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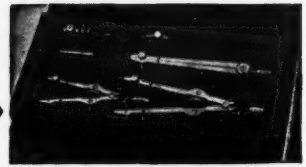

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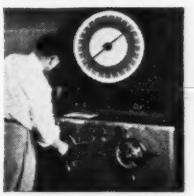

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It splits seconds even faster

In a split second, relays, which are high-speed switches, set up dial telephone connections. Then they are off to direct the next call. Yet even this speed is too slow for Bell Laboratories scientists in quest of still faster switching.

Scientists and engineers devised a new relay—the wire spring relay—and worked out the production problem with Western Electric, manufacturing unit of the Bell System. This is twice as fast, uses less power and costs less to make and maintain.

With speedier relays, switching can be done with less equipment . . . and calls go through faster. The wire spring relay is a practical example of how Bell Telephone Laboratories and Western Electric pool their skills to improve telephone service while keeping its cost down.

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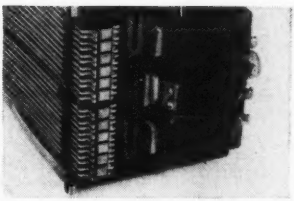
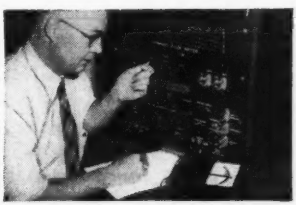


New relays must be able to operate one billion times—equal to once-a-second for 30 years. Employing a sound recorder as a precision vibrator, Bell scientists learned to evaluate the effect of sideways motion on relay life. Such rubbing motion is limited to one-thousandth of an inch in the new relays.



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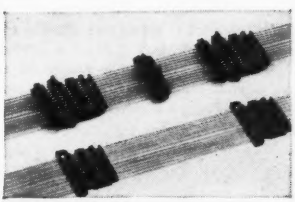

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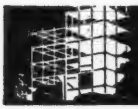

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The following six papers were presented at the ASEE Centennial Symposium on Engineering Education and Training under the Chairmanship of A. A. Potter, Dean of Engineering, Purdue University, September 4, 1952.

History of Engineering Education by Frederic T. Mavis

Achievements to Date in Engineering Education by Thorndike Saville

The Technical Institute—Its Relation to Engineering Education and Trade Training by C. W. Beese

The Engineer and the Scientist by W. F. G. Swann

Looking Ahead in Engineering Education by S. C. Hollister

Looking Ahead in Engineering Education by L. M. K. Boelter

History of Engineering Education*

By FREDERIC T. MAVIS

Professor and Head, Civil Engineering Department,
Carnegie Institute of Technology

Introduction

Dr. Harry P. Hammond, Dean Emeritus of Engineering at the Pennsylvania State College, was originally scheduled to speak to you on this subject—and no one is better qualified than he to brief the history of engineering education. When he became ill early in June, I was invited to pinch-hit for him and to adapt for this meeting a talk I had given in March to the West Virginia Section of the American Society of Civil Engineers and excerpted in *Carnegie Magazine* in June under the title, "Our Engineering Heritage." I am very happy to do this, realizing (as each of you does) that the history of engineering education can not be skimmed in thirty minutes, even with such able discussers to supplement or to correct what I may say. Moreover, the *history* of engineering education (which is my assignment) can only with difficulty be fenced off from the *achievements* in engineering education which is the topic assigned to Dean Saville who will speak to you later. Accordingly, I shall limit my remarks to *origins and growth* of engineering education and to the *heritage of ideas* that may help set up a reflective mood in this Centennial Symposium.

Engineering in its broadest terms is the art of directing the great sources of power in Nature for the use and convenience of man. It is an art as old as civilization itself, because men have always had to wrestle with the power of Nature.

Men must obey Nature's unwritten law. They may yield to it passively . . . or by their ingenuity and enterprise bend it to their own convenience and use. Nature does not change her course because men argue—however eloquently—that things should not be as they are; nor is she impressed by strong muscles and bluster. Yet all around us there is evidence that fierce Nature can be transformed into a useful servant or a household pet by those who will *learn* her ways, and *plan ingenious means* to work in harmony with her. The story of man's *learning* and planning to adapt power in nature to his use and convenience is primary; the story of his *teaching* is secondary. Learning and teaching go together, and a few diligent students will soon reflect the strength of their teachers . . . but what can a teacher do among "students" who will not learn?

If engineering arts are as old as civilization, engineering education can not lag far behind. I shall fall back on legend and history to support what I have to say.

The Mosaic Legend

Probably no other legend is more deeply rooted in our mores than the legend of the creation and the fall of man—the legend of Adam and Eve, of Cain and Abel—and there has been much speculation about where Cain got his wife. The First Book of Moses is often tiresome with geneology and "begats," but it merits thoughtful reading for my

* Presented at ASEE Centennial Symposium on Engineering Education and Training, Chicago, Illinois, September 4, 1952.

present purpose of engineering and education.

When Cain was banished, he got his wife from the land of Nod and raised his family there. (What engineering teacher doesn't get his eight-o'clock classes from the same place and keep them there much of the time he is lecturing?) According to this legend, Cain built a city which he named after his first son Enoch. Today, the job of planning cities, of building them, of supplying them with water and with facilities to remove wastes, of providing ways that men and goods can be transported efficiently in and between cities, often of managing municipal enterprise itself . . . is the work of a civil engineer. Whether Cain was the first woman-born civilized man is not important; but the legend that he constructed the first engineering works of civilized man by building a city is interesting. The Mosaic legend is not in conflict with my first premise that, whatever it may have been called, civil engineering is coeval with civilization. And all other branches of engineering as we know them today—except *strict* military engineering—have grown from the main stem of civil engineering within the last hundred years.

If you follow the line of "begats" you will find the sixth lineal descendant of Adam in the *Cainite* line is Lamech, son of Methusael, who introduced polygamy by marrying Adah and Zillah. Between A—and Z—he had three sons who fathered a good bit of civilized enterprises themselves. According to the Mosaic legend:

> "Jabal: he was the father of such as dwell in tents and such as have cattle." (Genesis 4: 20.)
> "Jubal: he was the father of all such as handle the harp and organ." (Genesis 4: 21.)
> "Tubal-cain, was an instructor of every artificer in brass and iron." (Genesis 4: 22.)

If you follow the "begats" in the *Sethite* line you will find another Lamech, who was a son of "old man" Methuselah and the father of Noah. Noah may have been the world's first flood forecaster and shipping magnate! The Mosaic legend continues to say that—

> "Noah began to be an husbandman, and he planted a vineyard. . . ." (Genesis 9: 21.)

and to suggest that he was the first man to become drunk by consuming too much of the wine that was produced on his lands. (Wine in those days was a commodity much like money today!)

So it is recorded in the Mosaic legend that commerce, music, and *instruction in the mechanic arts* had their beginnings in the seventh generation of descendants of Adam by the *wicked* Cain; and that flood forecasting, shipping, and intoxication were introduced at about the same time by a descendant of the *good* Seth.

The span of years between Tubal-cain, "instructor of every artificer in brass and iron," and the engineering teacher of today is uncertain—but certainly it is long. Meanwhile, civilized man practiced irrigation and a crude art of surveying from earliest times, and he must have understood much more of the world about him than we are likely to give him credit for. I shall not discuss the structures, monuments, hydraulic works of the Egyptians and Babylonians; the architecture of the Greeks; the roads, bridges, buildings, aqueducts, baths, and water laws of the Romans; the specifications and contracting procedures of antiquity. I shall not speculate on the knowledge ancient engineers had of rollers, levers, pulleys, and inclined planes; of the theory of arches as well as of the practice of building them to be useful and beautiful for more than two thousand years; of the science of mechanics and its application to arts of peace and war; of geometry and astronomy; of logic, and the mind tracks of induction and deduction; of law to govern rulers and those they ruled; of rhetoric and the art of persuasion; of music and art and sculpture; of the education and training of youth. Yet all

these bear significantly on the advancement of civilization—and with it engineering and engineering education. Who today can expect to have his works live two thousand years from now? Yet that is exactly what is happening to the works of Archmedes in mechanics; of Euclid in geometry; of Vitruvius in building construction and engineering education; of Frontinus in water supply and law.

Heritage of Ideas

In the province of *ideas* it is not always easy to distinguish "old" from "new." Compare ideas about the education of an engineer today with Vitruvius' ideas about the education of an *architectus* 2000 years ago. (Incidentally, the *architectus* of Vitruvius' time is the common ancestor of today's engineer and architect. Since I am speaking of the history of *engineering* education I shall translate the Latin *architectus* into *engineer* and grant that *architect* would be an equally appropriate translation.)

After describing clearly the interplay of craftsmanship and technology in the work performed by the engineer, Vitruvius † suggested how the engineer should be trained. He said, in effect, that engineers "who without culture aim at manual skill cannot gain a prestige corresponding to their labours, while those who trust to theory and literature obviously follow a shadow and not reality. But those who have mastered both [skill and culture], like men equipped in full armour, soon acquire influence and attain their purpose."

The engineering student, he added, must have both a natural gift and also readiness to learn. For neither talent without instruction nor instruction without talent can produce the perfect master. [The engineer] should be a man of letters, a skillful draftsman, a mathematician, familiar with historical studies, a diligent student of philosophy, acquainted with music, not ignorant of medicine, learned in the opinion of lawyers, familiar with astronomy and astronomical calculations. . . .

To those who would wonder that anyone could master so many subjects Vitruvius said that all these studies "are related to one another and have points of contact. . . . For a general education is put together like one body from its members. So those who from tender years are trained in various studies recognize the same characters in all the arts and see the intercommunication of all disciplines, and by that circumstance more easily acquire general information." What more need be said of continued learning. . . ?

Vitruvius stressed the importance of being "fair-minded, loyal, and what is more important, without avarice; for no work can be truly done without good faith and clean hands. Let [the engineer] not be greedy nor have his mind busied with acquiring gifts; but let him with seriousness guard his dignity by keeping a good name." What more need be said of ethics?

We would be smug to assume that our ideas on engineering education today are so far ahead of ideas the Romans had 2000 years ago. We would be a little less than stupid to ignore other parallels between great peoples who lived and worked at opposite ends of twenty centuries of the Christian Era. To illustrate what I mean let me merely allude to such books as "The Wisdom of Confucius," by Lin Yutang; "Vitruvius on Architecture," by Frank Granger; "Frontinus and the Aqueducts of Rome," by Clemens Herschel; "The Notebooks of Leonardo da Vinci," by Edward McCurdy; "The Works of Francis Bacon," by Basil Montague; "The History of The Inductive Sciences," by William Whewell; "The History of Magic and Experimental Sciences," by Lynn Thorndike; "Aims of Education and Other Essays," by Alfred North Whitehead; "Conflict of Studies and Other Essays," by Isaac Todhunter; "Too Much College," by Stephen Lea-

† *Vitruvius on Architecture,*" Vol. I, Book i, Edited and translated by Frank Granger. Harvard University Press and William Heineman, Ltd. (1945).

cock; and—a current gem—"Engineers and Ivory Towers," by Hardy Cross and Robert Goodpasture.

The Romans reached front rank among civilized peoples about the first century A.D., and the end of their decline is usually marked by the burning of Rome near the end of the fifth century. The decline was a gradual process involving "bread and circuses"—more "bread" following more "circuses" in a dizzy spiral. People were unable or unwilling to see the inevitable dangers of political programs that give away "benefits" and take away personal rights and self-respect—and people and politicians coasted to destruction. The fall of Rome was brought about more by the fiddling of Nero and his predecessors than by the actual burning of the city of Rome!

Advancement in Medieval Times

Western Europe fell apart after Rome lost its lead, and a thousand years passed before a widespread revival of cultural progress was ushered in by the invention of printing in the fifteenth century. But this thousand years was not wholly dark. The monks made great efforts to keep civilization alive. One mendicant order, Brothers of the Bridge, built and maintained roads, bridges, and wayside shelters. "Ingeniators" or master builders were in great demand to build private homes for the nobles and to make and operate engines of war. The name "engineer" came into being for ingenious men who did engineering work. I need only to mention such names as Roger Bacon, John of Salisbury, Abelard, to suggest that science and education were not dead in the twelfth century either. Great changes were taking place with action of the Crusades counteracted by the knowledge that followed them back out of the East. Gunpowder had been invented and its use in war sounded death to the medieval castle. One common soldier with firearms was more than a match for many nobles in heavy armor!

A great revival of art and learning started in Italy, and it soon spread beyond the Alps. The mariner's compass was invented—and with it came new courage to explore more unknown worlds. A science of mechanics was firmly grounded—and with it came new courage to explore more of the world's unknown. Indeed, when Galielo was born in 1564 (about fifty years after Leonardo da Vinci died) the world was more than half medieval—and when he died in 1642 (the year Newton was born) the world was more than half modern. Good books were being printed and widely disseminated. The minds of men were as great as they have been in any age—and once they were free to think, they thought great thoughts that brought some of the greatest advances in all time. At the end of the medieval period the old art of casting bells and cannon was reborn as the art of making machinery and metal cylinders The modern world was being born—and among engineers and scientists who helped with the delivery are such men as Copernicus, Leonardo da Vinci, Stevinus, Galileo, Huygens, Newton, Pascal and Vauban

Progress in Modern Times

Before the eighteenth century, training for engineering was by apprenticeship. If you can get the right masters and apprentices together there is no better method; but it is not geared to handle large numbers of students. Schools for engineers grew out of the need for more well-trained men than the apprentice system could provide. It was the French who led in the development of engineering as an art-science in schools of higher learning, and other Europeans and Americans soon followed their lead.

Perronet, engineer to Louis XV of France was given the job of building a system of national highways. Realizing the importance of good technical training, he transformed his staff into a school of men working together in 1747, and this school was legalized and officially named the École des Ponts et Chaussées in 1775. Because of this, Perronet is

sometimes called the father of engineering education.

Great economic and political changes were taking place in France and America in the late eighteenth century. Equally great changes were taking place in engineering—in manufacturing, transportation, commerce, and agriculture. The spinning jenny and steam engine were invented and later the cotton gin. The industrial age had begun. A new shingle appeared in the professional world: John Smeaton, "civil engineer," had coined a new adjective to distinguish one branch of the engineering profession from another. Two famous technical schools were founded in the latter part of the eighteenth century: the Bergakademie at Freiberg in Saxony in 1766 and the École Polytechnique at Paris in 1794. Even so, engineers in England were trained by apprenticeship for many years.

American state universities came into being with the laying of the cornerstone of the University of North Carolina in 1793. The first student was Hinton James ‡ who became a civil engineer. He entered the University early in 1795, was graduated in 1798, and left in a "record book" the titles of original and "exceptionally meritorious" compositions that he presented on Saturdays. Little is known of subjects he was *taught* as a student; but the titles of his original compositions show that he *learned* science, business, and economic geography—sound preparation for civil engineers of his day. Later he became assistant to Chief Engineer [Robert] Fulton on navigation work, and superintendent of work for improving the Cape Fear River.

In America, where so many men have entered state universities, it is interesting to note that the *first* was to graduate and become a good civil engineer!

In the early 1800s power was applied to transportation, and all industry in Europe and America advanced rapidly. More technical schools were needed to train men who could lead and guide mechanized industry. In 1802 the United States Military Academy was established at West Point—modelel after the École Polytechnique. It was the first school of applied science in any English-speaking country. Other schools began engineering training: Polytechnic Institute of Vienna, 1815; Norwich, 1819; Royal Polytechnic of Berlin, 1821; Rensselaer, 1824; University College, London, 1840; and Harvard, 1847.

Formal engineering education now had taken firm root—even if it was highly mathematical and dealt largely with theory. Leadership was being transferred from continental schools to the United States. It is in our own country that we find real progress in formal engineering education during the next hundred years beginning in 1852.

1852–1859

In 1851 the first international exhibit was held in London. Industrial products from many countries were displayed and there was increased interest in technology. The American Society of Civil Engineers was founded in 1852, and engineering education went forward rapidly. After Yale added engineering to its program of study in 1852 and Michigan in 1853, there were six schools of engineering in America—and all of them are active today.

B. F. Greene, director of Rensselaer, studied methods and programs of engineering education in Europe and reorganized work at Rensselaer. In 1855 he published at his director's report, *The True Idea of a Polytechnic Institute*—a classic that merits study today. It is natural, he wrote, to question the utility of such studies as rhetoric and philosophy to technical men when the time spent in formal engineering education is so short. Yet there should be balancing elements in a course necessarily so materialistic. No studies, he reasoned, are more suitable than these [rhetoric and philosophy] for developing the mind and they should find a prominent place in the educational program of every polytechnic institution.

‡ I am indebted to Professor T. F. Hickerson for information about Hinton James.

Rensselaer was thus firmly established as a technical university and was influential in shaping engineering education in America.

1860–1879

In 1862—midway in the War Between the States—the First Morrill Act granted land for colleges of agriculture and mechanic arts. The number of publicly supported schools grew and each one that received land grants included engineering in its programs. Many private schools followed this lead. In the ten years before 1862 the number of engineering schools had grown from four to seven or eight, and by 1870 to seventeen. After the close of the Franco-Prussian War in 1871 there was increased activity in science and technology in Europe and this was reflected in the United States. The number of engineering schools had increased to 70 by 1872.

In a paper on "The Education of Civil Engineers," T. C. Clarke told members of ASCE in 1874 that the educational program should stress learning general principles in the schools and acquiring technical knowledge in practice. This was a highly controversial issue among engineers in 1870's. A. L. Holley argued the other side in a paper on "The Inadequate Union of Engineering and Science" read before the February 1876 meeting of The American Institure of Mining Engineers (founded in 1871). Engineering schools were laying too much emphasis on abstract principles, he argued; and he advised putting the actual practice first and the theoretical study later. Debate was brief but sharp, and the issue was referred to a committee to continue the discussion at a joint meeting of ASCE and AIME at the Centennial exposition at Philadelphia in June 1876.

Twenty-five engineers, prominent in education and practice, took part in this two-day discussion at Philadelphia. The concensus was that education to prepare real engineers must be broad—stressing essential underlying principles and a considerable range of so-called cultural studies. Practical training was also necessary early in the professional life of the engineer.

1880–1899

The exposition of 1876 in Philadelphia was the first in the United States, and it stimulated widespread interest in science and engineering. It is not surprising then that the number of schools which taught engineering increased to 85 by 1880.

The Second Morrill Act of 1890 provided further support for colleges of agriculture and mechanic arts. When the World's Columbian Exposition was held in Chicago in 1893, engineering was taught in more than one hundred schools, and interest in engineering was still growing. The Society for the Promotion of Engineering Education was organized under the chairmanship of Ira O. Baker, professor of civil engineering at the University of Illinois, as Section E of the World's Engineering Congress. Papers at that meeting were presented by men inspired—indeed it is a humbling experience to reread Volume One of *Engineering Education,* dated 1893.

1900–1919

In 1907 the Society for the Promotion of Engineering Education invited the "Founder Societies" in engineering and the American Chemical Society to appoint delegates to a joint meeting to report on the appropriate scope of engineering education and on the degree of co-operation and unity that might be advantageously arranged between engineering schools. The Carnegie Foundation for the Advancement of Teaching and the General Education Board were invited to appoint delegates the next year. The members of national technical societies, asked to express their opinions of the essential characteristics of an engineer, rated them in the following order of importance: 1. Character, integrity, resourcefulness, initiative. 2. Judgment, common sense, scientific attitude, perspec-

tive. 3. Efficiency, thoroughness, accuracy, industry. 4. Understanding of men, executive ability. 5. Knowledge of fundamentals. 6. Technique of practice and business.

C. R. Mann said in 1917 that the division of time in the 125 schools studied was 20 per cent to the humanities, 30 per cent to mathematics and basic science, and roughly 50 per cent to technical work.

By 1918 Dr. Mann's investigation was completed and his final report, *A Study of Engineering Education,* was published by the Carnegie Foundation for the Advancement of Teaching.

1920–1939

In 1922 the Council of SPEE proposed that another investigation be made of the objects of engineering education and the adequateness of the curriculum. Carnegie funds, and others, were granted. W. E. Wickenden was named director of the investigation and H. P. Hammond, associate director in charge of relations with engineering colleges. Many organizations and faculty committees helped in securing data and submitting reports.

The two-volume *Report of the Investigation of Engineering Education,* 1923–29 reached four main conclusions: 1. An undergraduate course should be a coordinated program of three stems of subject matter: science, engineering methods, and social relations. The last year should be focused upon the students' major subject. 2. The three stems of engineering education should be unified into one branch with unity of administration. 3. An undergraduate course should be four years in length. 4. A graduate should continue his development either by formal graduate study in a school or by individual study after he enters practice.

The Wickenden-Hammond reports guided engineering education through the post-war years of the 1920's and the depression of the 1930's. When he was president of SPEE in 1933, W. E. Wickenden said that during the ten years of the Investigation engineers had acquired an envied position among college teachers. A sense of unrest and uncertainty had given way to a sense of assurance. These were the happly fruits of the Board's wise policy of promoting a program of stimulation, rather than one of standardization.

But engineering, which had given birth to many industries, was itself feeling the pains of growth and social pressure during the 1930's. Engineering education had to examine itself again in its social and economic surroundings of the early 1940's. Charles F. Scott may well have set the stage for a new appraisal when he wrote: "What are the causes leading to new trends? . . . Our environment—the world about us—is changing. The science which engineers apply is expanding. . . . Development of engineering education depends upon the willingness and ability for adaptation to changing environment. . . . Is it to be . . . education via the scientific, engineering route, or specific engineering via the educational ladder?"

1940–1952

H. P. Hammond was chairman of the SPEE Committee on Aims and Scope of Engineering Curricula which published its report in 1940. The committee stated that the flexible four-year undergraduate curriculum, followed by graduate work, would meet needs better than a longer undergraduate curriculum; that the undergraduate curricula should be made broader and more fundamental through increased emphasis on basic sciences and humanistic and social studies; that there were advantages in the parallel development of the scientific-technical and the humanistic-social sequences of the engineering curricula; that the integrated program which extends throughout the entire undergraduate period should therefore be preserved.

Soon after the Hammond report was published the United States was a participant in World War II, and every engineer—student, teacher, and practitioner

—was buffeted by crises, hullabaloo, and an avalanche of directives. Engineering educators were bedeviled by changing winds. What lay ahead? What might be the pattern of engineering education after the war? Robert E. Doherty, then president of Carnegie Institute of Technology and president of SPEE, appointed a committee on engineering education after the war, and again H. P. Hammond was selected as chairman. The committee, reporting in 1944, found that the specific purposes are essentially those recommended in the 1940 report on Aims and Scope of Engineering Curricula. They advised that the humanistic-social stem should require a minimum of 20 per cent of the student's time and noted that unless instruction included the elements of practice, it would be in science rather than in engineering. Events had shown one major extension to be needed: a more positive indoctrination in civic and professional responsibilities.

Engineers Keep Pace

From legendary times until today, no men essential to human progress have kept in better step with the vicissitudes of civilized progress than engineers and their teachers. At the close of World War II college enrollments were decimated—and a few years later their burdens were increased more than tenfold. Yet they have not only survived this torrent of change—they have periodically taken their bearings in the light that history and mastery of their profession gives them—and they have projected into the uncertain future, plans which have been realistic enough to make engineering a little better, and our standard of living a little higher through periods of prosperity, depression, and war. In learning to deal with forces of Nature—to get in step with her and apply her laws to the material and economic welfare of all mankind—the engineer learns to deal realistically with things as they are; and he does does not waste too many tears about things that might have been. Our engineering heritage is in large measure the realism and strength and courage that one must acquire if he is to work in the vanguard of inevitable change. In dealing with the caprice of Mother Nature the engineer has been pretty successful; in dealing with the cussedness of human nature he has limitless challenges and opportunities ahead of him.

Who can tell what changes lie ahead? Engineers may study the "laws of politics" in days to come, and harness the overgrown giant of governing machinery which has become America's master, rather than her servant. Would engineers bungle that job more than politicians have done? Time only can answer that. But I would ask one rhetorical question in conclusion: could politicans have done as well in bending the forces of nature to man's convenience and use as engineers have done? The job of harnessing politics for the use and convenience of man is yet to be done—and we'd better begin now!

Centennial Issues of the Journal of Engineering Education

The December and January issues of the JOURNAL OF ENGINEERING EDUCATION contain papers which were presented at the Centennial of Engineering in Chicago in September. Extra copies of these issues can be obtained for $1.00 per copy by writing to the American Society for Engineering Education, Northwestern University, Evanston, Ill.

Achievements in Engineering Education[1]

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Introduction

The achievements in engineering education during the past century are contemporaneous with and an inextricable part of the achievements in the geographical expansion, industrialization, and urbanization of the United States during this same period. It is a far cry from the simple single curriculum in the physical sciences, mathematics, drafting, surveying, and the practical arts of construction available in the half dozen institutions professing to give "engineering" one hundred years ago to the twenty major curricula now accredited in one or more of 148 engineering colleges in the country. The three-year civil engineering curriculum (such as it was) in 1852 has not only proliferated into many specialized four-year undergraduate curricula, but has expanded to substantial post-graduate study and research in many fields.

Faculties have changed from a few scientists and practical men of good will concerned with the problems of transportation and the mechanical arts, to large groups of highly trained specialists versed in the theory and practice of a profession which has come of age. In 1852 there were probably no more than twenty-five or thirty scientists or professionally trained people in the engineering schools. Today there are about 7500.

Undergraduate enrollment increased from perhaps 250 in 1852, to 1400 in 1870, and to a peak in accredited engineering colleges of over 100,000 in 1940. Enrollment in these colleges decreased during the years of World War II, then increased to a maximum of about 230,000 in 1947, and has now (1951–52) declined to about 128,000.

Recipients of the first (bachelor's or equivalent) degree in engineering increased from about 25 in 1852 to over 48,000 in 1950. Declining enrollments since then have resulted in fewer graduates. From about 30,000 in 1952 it is estimated a minimum of some 18,000 graduates will be reached in 1956 with a moderate increase thereafter. During the past century the total number of engineers in the country has increased from a few hundred in 1852 to 7,000 in 1880 to over 400,000 in 1952. The accelerated demand for engineers is well illustrated by the experience of 5 major industries (manufacturing, mining, construction, transportation, and public utilities) in which the number of engineers per 100,000 workers has increased from 150 in 1880 to 1500 in 1950.[2]

Engineering colleges have increased from some half dozen in 1852 to 17 in 1870, 85 in 1880, 126 in 1918, and 148 in 1952. The latter figure refers to colleges having one or more curricula accredited by Engineers' Council for Professional Development. In addition there are over 40 colleges reported by the U. S. Office of Education as offering degree curricula in engineering, not accredited by ECPD.[3]

[1] Address at Centennial of Engineering, Chicago, Illinois, September 4, 1952.

[2] "Employment Outlook for Engineers." Bulletin 968. Bureau of Labor Statistics, 1949.

[3] There are 7 engineering colleges in Canada, whose curricula are recognized by the major Canadian engineering societies. These colleges had 5204 engineering students and 1869 graduates with first degrees in 1952.

Facilities have improved from the rented quarters used for many years by the first engineering school [4] to the respectable laboratories and classrooms of most of the accredited engineering colleges, and to the awe-inspiring and elaborate structures of a few of the great private and publicly supported institutions of today.

This quick review of certain quantitative achievements in engineering education during the last century presents no conception of the qualitative improvements which have taken place. Nor does it reflect the concern of the engineering societies and of engineering educators with changes brought about by the ever enlarging applications of science to industrial and agricultural pursuits and to the health and convenience of the people. These are the responsibilities of the engineer, and the success with which he meets them is dependent in large measure upon the scope and adequacy of his education. The purpose of this address is to describe briefly the major changes which have taken place over the past century, particularly during the last 50 years.

Curricula—The First Fifty Years

Prior to 1870 the chief aim of engineering curricula was to train civil engineers to meet the problems of an era of rapid geographical expansion and of growth in urban population. The instruction was largely confined to mathematics (algebra, geometry, trigonometry, and calculus); a year each of physics, chemistry, astronomy, geology, history and foreign language; two years of surveying, two years of English, and courses in the practical applications of "machines," "constructions," "hydraulic works," "earth work and masonry," and in some cases mining and metallurgy.

The rapid growth of industrialization following the Civil War brought about a demand for more varied, rigorous, and comprehensive education for engineers. This stimulated the establishment of many new engineering colleges and engineering departments in existing institutions. Beteween 1870 and 1890 the number of institutions offering formal programs in engineering had increased from 17 to 110. The Morrill Acts of the 1860's provided a powerful stimulus to the establishment of the Land Grant Colleges, where instruction in the "mechanics arts" rapidly evolved into engineering curricula. A number of schools of mining engineering developed between 1864 and 1880. Mechanical engineering began to emerge as an important separate curriculum in the 1880's, and electrical engineering in the following decade. Chemical engineering was offered by two or three colleges in 1900.

The period from 1870 to 1900 was one of transition. The major curricula in civil, mining, mechanical, electrical and chemical engineering developed in the order named from empirical and so-called "practical" instruction based on didactic teaching in the classroom to what became for the ensuing fifty years the conventional engineering curriculum, namely, four undergraduate years, the first two devoted largely to basic studies in the natural and mathematical sciences and the last two increasingly occupied with specialized courses pertaining to the particular professional discipline being pursued.

Dr. H. P. Hammond has pointed out that "in certain fields of engineering—civil, mechanical, mining—the art preceded the science, whereas in others—electrical, chemical and perhaps metallurgical—the science preceded the art. This evolution reflects itself in the relative extent to which the corresponding curricula have been largely empirical or scientific in nature."

A notable innovation, peculiar to American engineering education, was [5] "the

ECPD has not been requested to accredit any curricula in these schools.

[4] Rensselaer Polytechnic Institute, the progenitor of engineering education in this country, was founded in 1824, and granted the first engineering degree in 1835.

[5] "A Comparative Study of Engineering Education in the United States and Europe." W. E. Wickenden, Bulletin No. 16, The So-

great development in laboratory methods of teaching, a field where American leadership has been especially marked." Another contribution peculiar to engineering education in this country is the emphasis placed upon the economic, management and production phases of engineering, particularly in the development of separate curricula in industrial engineering.

Curricula—The Last Fifty Years

The period from 1900 to 1950 was not marked by any profound changes in either the philosophy or the practice of undergraduate education, except for the inauguration of the "cooperative plan" and the development of formal degree programs given in the evening in a number of the larger metropolitan centers. Both are described in other sections of this paper.

Curriculum Trends

During this past 50 years there has been a rather marked trend toward more rigorous treatment of the professional courses given in the last two years of the undergraduate curriculum. Scientific discoveries and advances in scientific knowledge have necessarily been reflected in their applications to engineering. To understand and to apply this new knowledge have in turn required more extensive study in mathematics and the physical sciences. A trend toward more such study in the undergraduate curriculum has been discernible but not marked during the past fifty years.

Increased emphasis has been given to the social-humanistic studies, but these must remain circumscribed so long as the present type of rigid undergraduate curriculum persists.

The proper and feasible balance between fundamental science, professional subjects, and the "art of engineering" has been a perennial subject of controversy. A description of the situation presented by Dr. Robert Fletcher of the Thayer School of Engineering in a paper before the International Engineering Congress in 1905 is applicable today. "Extreme views are held. Some would have the college programs cover an all-around training in fundamental subjects only, grounding the students in the basal principles of mathematics, mechanics and physical science, and those which determine engineering practice in general, giving due time also to broader culture, but giving only unavoidable attention to details. Others, arguing that this is above all things an age of specialists, would have the student begin to differentiate his studies with reference to some specialty even in the secondary school. Others claim the more common arrangement is necessary and sufficient, that which devotes two or three years of a four years course to the more general underlying subjects, and the final two years or one to study and practice in the special direction. Others argue that the specialty is the life work and should be begun last, and that the schoolwork therein is better done in a fifth or postgraduate year."

The slight trends toward more rigorous upper class subjects and toward more fundamental science in the lower class subjects have been paralled by a marked trend toward an increase in the number of separate undergraduate curricula both recognized and proposed. The five or six basic undergraduate curricula bearing the names of the great "founder" engineering societies began to have "splinters" break off after 1900, just as did the societies themselves. Just as separate organizations were formed for highway, railway, sanitary, radio, refrigeration, safety, power, automotive, ceramic, and other specialists, so newly designated curricula have proliferated in the engineering colleges, and in many cases using similar designations. Today twenty such curricula are accredited by ECPD, and proposals for more have been submitted. This subject is discussed further under the heading of "Accreditation."

The Cooperative Plan

Reference has been made to a notable experiment in engineering education which

ciety for the Promotion of Engineering Education, 1929.

has statistically had a rise and fall during the past half century. The "Cooperative Plan of Engineering Education" was inaugurated at the University of Cincinnati in 1906 by Dean Herman Schneider. This is defined [6] as "an integration of classroom work and practical industrial experience in an organized program under which students alternate periods of employment in industry, business, or government." This plan had considerable vogue between 1910 and 1930, but as late as 1949 only six of the 148 accredited engineering colleges require it for all of their undergraduate students. Twelve others utilize the plan for some of their students, either on an elective basis or for a particular curriculum or group. Eleven accredited engineering colleges adopted the plan, and subsequently abandoned it. The plan is markedly successful in many of the 18 accredited institutions utilizing it for all or a part of their students. It has obvious advantages of the "learning while doing" character. Its success depends upon continuous and rather expensive supervision by the educational institution of the kind of practical work in which the students are engaged and the coordination of such work with the curriculum content at a given time. The failure of the majority of accredited engineering colleges to adopt or to continue the cooperative plan is believed to be due to a variety of difficulties, of which added length of time to receive a degree, greater cost, difficulty of suitable employment in depression periods, and objection of labor unions are among the more important. The increased availability of engineering curricula given in the evening in larger metropolitan centers (discussed elsewhere) provided a less expensive and in part a more realistic substitute for the formal cooperative plan.

Evening Degree Programs

By the early 1920's four institutions in New York City, one in Washington, and one in Pittsburgh had begun to offer formal engineering curricula in the evening for which degree credit was given. The first ECPD accrediting committee had some misgivings as to the adequacy and equivalency of these programs as compared to the usual four-year full-time day program. However, after some study and the reports of special subcommittees, four such curricula were accredited in 1936, three in New York and one in Pittsburgh. By 1951 ECPD had accredited evening programs in only six institutions, three in New York, one in Newark, one in Pittsburgh and one in Cleveland. However, many of the engineering colleges accredited for full time day curricula are offering unaccredited evening programs of substantial size. The six institutions having accredited evening programs reported approximately 6500 students enrolled in 1951, out of a total of 13,400 evening students in all of the accredited institutions. There were 3500 evening students enrolled in evening degree programs in 1924.

The evening programs are primarily designed for those financially unable to pursue a four-year full time day prgoram. Such students are employed during the day time, frequently in sub-professional occupations analagous to those utilized under the cooperative plan. To a degree, therefore, evening programs represent a modification of that plan. The evening programs require a minimum of six years, and customarily six and one half to eight years before the first degree is obtained. These programs, when carefully and conscientiously administered, are proving in all respects the equal of the full time day programs. There are tendencies which have to be watched to be certain that course content, student performance, and quality of instruction are maintained on a satisfactory basis. In some institutions an undue number of students may be enrolled in evening programs who are not primarily interested in obtaining a degree, but are more concerned in the vocational utility of a single course or a few courses.

On the whole, carefully formulated and well administered evening engineering cur-

[6] "A Survey of Cooperative Engineering Education." Bulletin No. 15, 1949, U. S. Office of Education.

ricula are supplying a needed opportunity for students unable to finance a full time day program, and the graduates from these programs constitute an important supplement toward helping meet the demand for more engineers. The programs have been successful in the few metropolitan centers where they have been operated for many years, and there is a real need for the development of additional accredited evening curricula in a good many other areas, particularly where manufacturing industries can supply a sufficient volume of students.

Faculty

Obviously the quality of instruction in engineering is dependent largely upon the calibre of the faculty charged with imparting it. Just as instruction and curricula content have tended to become more rigorous and more specialized, so has the calibre of the faculty tended to become more learned and more competent in special areas of science and technology. The early engineering teachers were scientists or practical men who looked to Europe, and particularly France, for the engineering and scientific texts and treatises which formed the basis for most of the formal teaching. Since 1880, and particularly during the last fifty years, an entire literature of engineering education has become established in this country, which for careful preparation, scope of coverage, theoretical and practical content, and excellence of format has no equal in the world. This literature has increasingly reflected the growing stature of our faculties.

Another index of the accomplishments of the teaching staffs may be measured by the great increase in the per cent of the total number which hold advanced degrees. From the rather sparse and unsatisfactory statistical data which exists it is probable that during the past fifty years the per cent of faculty members engaged in teaching engineering subjects who hold an advanced degree has increased from perhaps 25% in 1900 to about 45% in 1920, to 60% in 1940 and probably to at least 75% at present. Some concern has been expressed lest too great emphasis is being placed upon advanced degrees, particularly the doctorate, as a prerequisite for faculty advancement or appointment to the higher grades. But since the employers of engineering graduates evidence an increasing desire for a greater proportion who have a post-graduate degree, and pay an attractive differential for them, it is essential that the instructors be qualified to prepare such graduates. More important than this, however, is the constantly increasing scope and breadth of engineering which requires the members of a competent faculty to have intellectual and scientific attainments of which possession of an advanced degree provides at least some assurance.

Many professional members of faculties are engaged for a part of the year either in actual practice of their profession or in research in one of its specialties, or both. The great increase in number of faculty engaged in research is mentioned elsewhere, and most engineering colleges today encourage both outside practice and research in moderation. Moreover, there is a constant infiltration of engineers from industry and government into the faculties, a procedure having much to commend it, but increasingly difficult under current conditions of higher salaries in practice. The reverse practice of industry's enticing promising young faculty members away from engineering colleges by higher salaries is a problem familiar to all of us. Some attention is being given to exchange arrangements with industry, whereby engineers in industry and in engineering college faculties will be given concurrent leaves of absence for a year to fill each other's places. Arrangements of this sort, if widely adopted, may do much to broaden engineering teaching and be equally beneficial to the cooperating employer.

The character of the man, the composite of his personality, his professional achievements, his concern about students and about engineering, his philosophy of life, all are important elements in selecting a teacher. The securing of the right kind of teachers has always been a major problem

in engineering education, and it remains so today.

Graduate Study

Prior to 1890 there were only six institutions which had conferred advanced degrees in engineering. Only three earned doctorates had been conferred at the end of 1896. It was not until the second decade of the present century that any substantial number of graduate students were enrolled or post-graduate degrees conferred. Since then the accelerated impact of science upon engineering and technology has created an ever increasing need for engineering graduates who have been educated in specialties beyond the extent possible in a four-year undergraduate program. By 1921 some 40 engineering colleges were offering graduate work, 368 graduate students were enrolled, and 178 post-graduate degrees were awarded. However, some of these degrees were awarded by institutes of technology and were in such fields as chemistry, biology, geology, etc. The first differentiating statistics appear in 1934, when graduate registration totalled about 2800 and post-graduate degrees awarded numbered nearly 1200.

Prior to the outbreak of World War II, graduate registration in 1939–40 had increased to 4582 enrolled for the Master's degree (1318 degrees awarded) and 624 for the Doctor's degree (108 degrees awarded). The phenomenal developments in the applications of science which took place during the war years created a marked increase in the demand for engineers with post-graduate education. The engineering colleges were quick to respond, too quick upon the part of some institutions not adequately equipped in faculty or facilities. Enrollment for the Master's degree in 1951–52 was 16,452 (5134 degrees awarded) and 2875 for the Doctor's degree (586 degrees awarded). It is interesting to note that with a declining enrollment in undergraduate curricula for each year since 1947, there has each year been an *increase* in graduate enrollment.

An interesting comparison may be drawn between evening work on the undergraduate levels. About 10% of the total number of undergraduate students are enrolled in evening programs, whereas 10,000 (52%) of the 19,300 graduate students are enrolled in programs or courses given in the evening. At least 23 institutions have enrollments of over 100 graduate students in evening courses. Nearly all of these are in industrial centers. The magnitude of these evening graduate programs is an indication of the extent to which engineering colleges have met the demand by employed engineers for further education. The evening courses are in some instances given in cooperation with industry (as in the Westinghouse program) and in many instances the employer subsidizes all or part of the cost of the employee's education. Also many students who did not exhaust their veterans' benefits are using this means of acquiring post-graduate education while employed.

Research

Research as performed in engineering colleges may be broadly defined in two categories, (a) that undertaken by faculty members and graduate students to advance knowledge and supported by institutional resources or by grants from foundations, and (b) that sponsored by government agencies or private industry. Prior to World War II the major research activities of the privately-endowed institutions were predominately in class (a), and class (b) sponsored research was performed chiefly in the land grant colleges through their engineering experiment stations.

Before 1940 research was recognized as contributing significantly to education in attracting scientifically minded men to the faculties, in the stimulus it gave to instruction, and as a necessary element in post-graduate education. However, nearly every report of groups investigating engineering education from time to time deplored the meagerness of research activities at all except a few of the larger or more enlightened institutions. Beginning about 1940 in a few institutions peculiarly

adapted for research in special applications of science to the war effort, the support of research by federal government agencies has reached large proportions and is distributed among a good many engineering colleges. Nearly all are seeking more.

The contributions of the engineering colleges to the applications of science to new developments and processes have been tremendous during the past decade. A great service has been rendered the nation, and many institutions, faculty members and students have benefited in various ways. No longer may it be said that engineering colleges are not sufficiently alert to research. But the availability of such great amounts of federal funds for sponsored research has brought its problems to the colleges, problems of some magnitude and not yet resolved. Among them are dangers from the preoccupation of some faculty with research projects to the detriment of good teaching; the assignment of good teachers to research projects for all or a significant portion of their time; and the restriction of federally-supported research programs to those of interest to a given agency, to the detriment of prosecution of more basic or fundamental research on which faculty members might prefer to be engaged.

From what has been said above, the question will at once be asked: What has industry done to encourage research in the engineering colleges, one of whose major functions is to supply industry with well-educated personnel? Unfortunately, and somewhat illogically the answer is: an insignificant amount when measured by its reliance upon engineering education for its present existence and its future performance.

The leaders of industry have naturally and properly been alert to decry the tendencies toward a socialistic or paternalistic state, and argue for more reliannce upon the "free enterprise" concepts of our original democracy. Yet, although engineering provides both the intellectual and physical basis of industrial design, production, and management, the support of engineering education through wise policies of assistance without attempts to control, has been stranngely lacking on the part of a considerable segment of our business community other wise notable for its prescience.

Industrialists have been frank, and often indiscriminating if not ignorant critics of engineering education. They have been prompt to support measures to ensure their continued supply of engineering graduates (as within the present framework of the Engineering Manpower Commission), but they have conjured up every conceivable argument and legal device to excuse them from any considerable support of the educational institutions upon whose graduates their future is based. To research, which might be supposed to represent an area of support which would offer a quid pro quo, their contributions on the whole have been relatively small in amount and not administered according to any broad policy. To be sure some industries have made fairly substantial grants for research usually in some developmental field of direct interest to them, but the support of basic research in engineering has been extremely meager considering the vast industrial interests involved. The support of graduate fellowships by industry has been somewhat better, and a real achievement has taken place in the past few years with the establishment of a number of quite generous fellowships by a few large industries with no strings attached. Doubtless the situation is not entirely the fault of industry, and there is need for Engineering Education to do more to convince industry that its support of research is warranted on a much larger scale than has been experienced heretofore.

Out of the present situation there will undoubtedly emerge more rational and yet adequate policies and procedures which will enable the engineering colleges to give to research its proper place in a broad program for engineering education which it is their chief concern to formulate and continuously to improve.

Auxiliary Educational Services

The major obligation of engineering education is to develop graduates who are competent to practice and to lead in the profession. However, from time to time engineering educators are called upon in the interest of the public welfare or safety to render educational services auxiliary to professional education. For many years engineering colleges, particularly those supported by public funds, have operated courses of relatively short duration for the training of sub-professional personnel. The "short schools" for water works operators, highway personnel, power plant operators, and the like have rendered and continue to render a distinct public service.

"During the first World War the engineering colleges of the country were responsible for a major portion of the vocational training programs of the U. S. Army, which was almost entirely concerned with the training of mechanics, and gave practically no attention to training on the engineering level." [7] Except in relatively circumscribed areas, continued production of professional engineering personnel was not regarded as an essential element in winning the war, and the engineering colleges were thus allocated a program of sub-professional character which they performed with versatility and enthusiasm.

Perhaps the greatest contribution of engineering colleges as a group to the prosecution of World War II was the Engineering, Science, and Management War Training program under the auspices of the U. S. Office of Education. "More than 1.5 million men and women received special training during the period October 9, 1940 to June 30, 1945 in short intensive college level courses designed to prepare for technical and scientific work in war industries. . . . The Federal Government expended nearly 60 million dollars to cover the actual costs incurred." [7] This program was conceived, organized, administered and operated by the engineering colleges of the United States.

Two sentences will suffice to describe the ASTP (Army Specialized Training Program) of the latter part of the World War II period. It was conceived by the War Department, a fantastic substitute for collegiate education dreamed up by the military and "professional educators" (not engineering) and designed primarily to produce badly needed engineers for the armed services with some specialists in linguistics and other areas in an abbreviated curriculum. It was a dismal failure from the standpoint of engineering education in which the engineering colleges participated reluctantly both as a national duty and as a substantial alternative to educational oblivion.

Certainly one of the great achievements of engineering education in this country has been its freedom from any dogmatism that its obligations were fixed toward any narrow professional objective. It has continuously demonstrated an adaptability to serve as national needs or military dicta required in times of emergency, and to guide and help in many areas auxiliary to its major purpose in times of peace.

Relation to the Engineering Societies

It may be stated unequivocally that engineering education enjoys a relationship to the engineering societies unique in the annals of professional education. No other profession has any organization of its educational members comparable to the American Society for Engineering Education. No other profession has an association of professional societies devoted to educational and related activities comparable to Engineers' Council for Professional Development. It is not surprising therefore that engineering education in the truly professional sense has developed rapidly since 1893 when the predecessor of the ASEE was established, and that the impact of the profession itself upon the education of its practitioners stems from the establishment of ECPD in 1932. No system of professional educa-

[7] "Engineering Science and Management War Training," Bulletin 9, 1946, U. S. Office of Education.

tion could remain static or complacent when subjected to the constant scrutiny of the committees and divisions of its own members supplemented by continuing appraisals and criticisms from a group representing the major professional societies and the licensing boards of the several states.

The American Society for Engineering Education

The Society for the Promotion of Engineering Education was organized at the Congress of Engineers held in connection with the great World Columbian Exposition in Chicago in 1893. Engineering Education was Division E of the Congress. Professor Ira O. Baker of the University of Illinois was chairman, and Professor C. Frank Allen of the Massachusetts Institute of Technology was secretary. Both were members of the American Society of Civil Engineers, and Professor Allen in rendering his secretarial report stated "that a society had been organized by the members of the Division for the promotion of engineering education." Thus one may say that the Society whose centennial we are now observing in a sense fathered the Society for the Promotion of Engineering Education. Weight is lent to this by the fact that two of the first three and fourteen of the first twenty five presidents of the Society were members of the American Society of Civil Engineers.

The Society for the Promotion of Engineering Education began with 70 members, which has now (1952) increased to over 7000. It early started studies of various facets of engineering education, and initiated in 1907 a practice followed from time to time ever since, a request for the professional engineering societies to collaborate in its major investigations. In that year it invited the societies of the Civil, Mining, Mechanical, Electrical and Chemical Engineers to join it in forming a Joint Committee on Engineering Education,[8] to explore all of the aspects of the subject. The Committee was organized, and the American Society of Civil Engineers in 1908 made an appropriation for its operation, the first recorded grant from an engineering society for an investigation of engineering education. However, the Committee still lacked adequate funds for its investigation. In 1916, the Chairman of the Committee, Desmond Fitzgerald, who was President of the American Society of Civil Engineers, reported that "after we (ASCE) had spent all our spare cash in carrying on the work of this Committee, we naturally turned our eyes to the Carnegie Foundation."[9] The Carnegie Foundation undertook the task, and in 1918 issued a report by C. R. Mann entitled "A Study of Engineering Education."

This report was the first of a number of significant studies and investigations into the general field of engineering education sponsored jointly in one way or another by the Society for the Promotion of Engineering Education (or its successor) and the professional engineering societies.

The Society was reorganized in 1946 to provide for more effective administration and better recognition of the several elements in engineering education; viz. the individual teacher, the work of Committees and Divisions, the geographical sections, administration, and research. The name was changed to the American Society for Engineering Education. The Society has individual membership and also associate membership for organizations having a major interest in engineering, such as industries, research institutes, and the like. It has always had, as active members, many who were prominent in practice, such as presidents, chief engineers, and personnel managers of industry. This has provided important stimuli for many activities, and has introduced an important element of consideration of prac-

[8] The member societies of this Committee now constitute (with the National Council of State Boards of Engineering Examiners, and the Engineering Institute of Canada) the Engineers' Council for Professional Development.

[9] Proceedings, Society for the Promotion of Engineering Education, Volume XXIV, 1916, p. 46.

tical and present needs into its many achievements. The Society has active Divisions constantly concerned with improvements in instruction in the several curricula and the major supporting sciences and non-technical subjects. It has various special committees which have from time to time issued notable reports which have had a profound influence upon engineering education. The best known, most exhaustive and most influential of these was the "Investigation of Engineering Education," a monumental study extending over ten years (1923–34) financed by the Carnegie Corporation, the Engineering Societies, and certain industries. It still forms the platform from which later studies have taken off.

The American Society for Engineering Education is an extraordinary phenomenon in professional education. There is nothing approaching it as related to the other professions. Its achievements and the constant pre-occupation of hundreds of its members with major facets of engineering education are too little appreciated by the profession which it serves. Its annual meetings are attended by upwards of 1000 of its members, where they discuss reports of committees, and papers dealing with new educational ideas or procedures. An enumeration of the names of a few of its Divisions and Committees is illustrative of its concern with current problems. In addition to the Divisions dealing with all major curricula and supporting courses, there are Divisions of Relations with Industry, Graduate Studies, Technical Institutes, etc. Its major committees include Selection and Guidance, Research, Atomic Energy Education, Young Engineering Teachers, and Improvement of Teaching. Its Manpower Committee was the progenitor of the Manpower Commission of Engineers Joint Council. Reference will be made later to a new Committee on Evaluation of Engineering Education.

The publications of the Society have a world wide distribution, and are regarded as authoritative sources of historical background, current practice, and statistical data. They have had a substantial influence upon engineering education in this and other countries.

Engineers' Council for Professional Development

As the engineering profession became larger in numbers, as an increasing proportion of its members were college graduates (from perhaps 25% in 1852 to 85% in 1952), as the engineering societies grew in numbers and influence, a professional consciousness developed which in 1932 produced a need for Engineers' Council for Professional Development. The six societies which participated in the Joint Committee on Engineering Education in 1907 (ASCE, AIME, ASME, AIEE, AIChE, and ASEE) initiated steps to form the Council and invited the Engineering Institute of Canada (EIC) and the National Council of State Boards of Engineering Examiners (NCSBEE) to participate.

The ECPD is a conference body commissioned "to promote efforts toward higher professional standards of education and practice, greater solidarity of the profession, and greater effectiveness in dealing with technical, social, and economic problems."[10] It will be noted that engineering education was regarded as of prime importance, and it has continued to be one of the major concerns of ECPD. This concern has been implemented by the activities of two standing committees over the past twenty years, those on Education and on Guidance. The Committee on Education (originally the Committee on Engineering Schools) has dealt with accreditation of engineering curricula; that on Guidance (formerly Student Selection and Guidance) with information on engineering as a career supplied to secondary school students, and with the determination of aptitudes for engineering study in the development of testing procedures. More recently a new and important committee has been established, that on Ade-

[10] "ECPD—A Challenge." Booklet issued in 1947 by ECPD.

quacy and Standards of Engineering Education.

Accreditation

Engineering Colleges. By 1932 over 135 institutions of higher education were offering degree curricula in engineering. It had become obvious that marked differences occurred in educational standards, the strength and breadth of curricula, the qualifications of faculties, and the adequacy of facilities. Some process of determining the composite of these criteria as a basis for recognition of the graduate as acceptable for membership in the professional societies and for admission to state license examinations was obviously needed. The growth of state licensing laws was beginning to develop a danger that separate accrediting procedures would be set up in each state, with resulting differences in standards and practices and general confusion. Hence ECPD created the Committee on Engineering Schools (now the Committee on Education) to represent the entire profession and the state licensing boards. This was a formidable and delicate task. Hence a distinguished committee was appointed under the chairmanship of President Karl Compton of the Massachusetts Institute of Technology and members representing the participating societies of ECPD. The Committee spent four years in making its initial studies, and published the first general list of accredited curricula in 1937. Of 626 curricula inspected in 129 institutions visited, 374 were accredited for a limited time and 71 accredited provisionally in 107 institutions. Action was deferred on 8, and 173 were not accredited. The Committee has continued its activities, and as of 1951 680 curricula are accredited fully or provisionally in 148 institutions.

There is not space to describe in detail all of the policies and procedures affecting accreditation, but the operations of the committee represent some major achievements in engineering education. Therefore, since the accrediting process has profound implications upon the progress of engineering, and since the rapid increase in attainments required by the engineer and the enlarging diversity of his employment have raised anew some old problems and have created new challenges, a brief resume of the basic principles heretofore applied to the accrediting process is in order.

1. Only specific curricula, not institutions, are accredited.
2. Inspection with a view toward accreditation is made only upon the invitation of an institution.
3. The purpose of accreditation is to identify those institutions which offer professional curricula in engineering worthy of recognition as such, and shall apply only to curricula leading to degrees.
4. Only undergraduate curricula have thus far been accredited.
5. Accreditation is based upon both qualitative and quantitive criteria, but no "standards" have been formulated or applied. Accreditation is based largely upon the over-all judgment of a qualified inspection committee, which applies general criteria listed in each annual report of ECPD.

The original intention of ECPD was to recognize for accreditation only the six major curricula, but as mentioned previously the proliferation of engineering societies was paralleled by a proliferation of engineering curricula. Pressures from the engineering colleges and from segments of the profession itself forced the Committee on Education to recognize additional curricula. The first list of accredited curricula (for the New England and Middle Atlantic states only) published in 1936 expressed the principle that "ECPD will recognize the six major curricula (chemical, civil, electrical, mechanical, metallurgical and mining engineering) represented in its own organization, *and such other curricula* as are warranted by the educational and industrial conditions pertaining to them." This left the door wide open, and in the very first list referred to above fourteen curricula are

recognized, thirteen of which (the largest at any institution) were offered at MIT.

Since then proliferation has continued to be resisted by ensuing ECPD committees, but it has been a losing battle. The latest (1951) ECPD report lists 20 different accredited curricula. Applications are pending from various engineering colleges for recognition of some 15 new curricula, ranging from coal mining engineering to fire protection engineering. All that is needed is a curriculum in combustion engineering and we will have a trinity of engineering specialists, one of which will procure the fuel (coal mining), the next will burn it (combustion engineering), and the third will put out the fire (fire protection engineering)!

Technical Institutes. The provision of appropriate education for those who serve the engineering profession in sub-professional capacities, as engineering aids, technicians, and the like, has long been a subject of discussion. ASEE reports twenty years ago called attention to the importance of such education, and urged the recognition of technic institutes for their necessary and avowed purposes, lest many more be tempted to follow the example of some, and metamorphose themselves into weak engineering schools. Recognizing the importance of technical institutes in the general scheme of technical education, a Division of Technical Institutes was established in ASEE after World War II. In 1945 ECPD undertook to extend the accrediting process to technical institutes which offered two year terminal post-high school programs.

A subcommittee of the Committee on Education of ECPD administers the accreditation of Technical Institutes. Twenty-three are now (1951–52) accredited. The accreditation process is based to a degree upon the criteria described above for engineering colleges, with due allowance for the different type of curricula and objectives. Technical Institutes have come of age. The guidance provided them and the recognition accorded them represent an important achievement by engineering during the past decade.

Yet the role of the technical institute is not yet what it should be in the overall concept of education for engineering and its related technology. The situation is well expressed in a personal communication to the writer of this paper by Dr. H. P. Hammond, who guided the Technical Institute accreditation policies of ECPD through the first five years. He states:

"I think it is significant and important to point out that the number of technical institutes is inversely in proportion to the number of engineering colleges as the need for them exists in this country. Broadly speaking, and with exceptions, they are inadequate also in quality to produce the sub-professional technically trained personnel needed by industry and government. The result is that the engineering colleges are forced to carry a load of what is actually subprofessional training for poorly qualified students who will never become genuine professional engineers. And many colleges are perfectly willing to do it. This is one of the greatest sources of low standards of accreditation. It is the reason I advocated the establishment of the subcommittee on technical institutes and this had some benefits, I think, but it has not accomplished what I hoped it might and it never will unless industry, the profession itself, and the colleges get a new conception of engineering as a professional pursuit and of technical institutes as the appropriate source of subprofessional technicians."

Guidance

The selection of qualified students for admission to engineering colleges has been a matter of study and experiment ever since the Mann Report of 1918 called attention to the promising tests developed by Thorndike and by Thurstone. Subsequently the ECPD has collaborated with ASEE and many engineering colleges in the development and application of various testing programs. The most ambitious was the Measurement and Guidance Project in Engineering Education operated from 1943 to 1948. Substantial financial support was furnished by the Carnegie Foundation. The project was absorbed into the Educational Testing Service when that was created in 1948 to merge a num-

ber of testing programs. Many engineering colleges have used many testing devices to attempt to select better their entering students, and to predict their subsequent performance in engineering. Nearly all have been modified, and experimentation continues. This fact of engineering education contains many unresolved and debatable problems.

Adequacy and Standards

From time to time as engineering expanded as a profession, as it felt the impact of new scientific knowledge, as its graduates were catapulted into fields where applied science or other professional disciplines required both the specialized knowledge and skill of the engineer, recurring controversies have arisen as to (1) the content of the engineering curriculum, (2) its objectives, and (3) its length. Another such period of inquiry and decisions is upon us. ECPD recognized this by the creation in 1950 of a Committee on Adequacy and Standards. Its first report was published in 1951. This report called attention to the wide variation in the quality of engineering curricula, even though they met the minimum standards imposed by the accrediting procedure. It pointed out the need for more adequate knowledge of the fundamental sciences, the different methods in use for relating this knowledge to engineering education, and the basic premise that the "Differentiating characteristic of the engineering function is the ability to utilize the sciences for the creative process of design and development of useful apparatus, structures, or other works. . . ." The Committee suggested a reappraisal of engineering education which is now under way.

Conclusion

The foregoing account of some of the major achievements in engineering education during the past century had perforce to omit many significant developments, experiments, and related topics. It should be clear that progress in engineering education has been substantial, and that the achievements are significant and numerous. But it is equally obvious that serious problems still confront us, of which curriculum content, proliferation of curricula, length of the undergraduate curriculum, post-graduate education, and selection and guidance are among the more important. The ASEE and ECPD have recognized the challenge, and there was established by ASEE in June 1952 a Coordinating Committee on the Evaluation of Engineering Education. The results of this inquiry will undoubtedly mark an important milestone in the future of professional education in engineering.

The major objectives of this important study will doubtless be described in the last papers of today's program. Suffice it to say here that the continued alertness of engineering educators and the engineering societies to meet the ever-expanding requirements of sound and adequate education for the engineering profession has been productive of substantial achievements. But this very alertness and the lack of complacency which has happily characterized these groups, especially during the past half century, have created an awareness that the time is at hand for some serious soul searching to insure equal achievements for the future. There is a ferment at work which has had as its first product the initiation of the evaluation process just mentioned.

The real measure of the accomplishments in engineering education is in the contributions of its product to the profession of engineering. The recognition accorded that profession; the almost fantastic progress in industrial development and production conceived and managed by engineers; the great structures designed and built by them for the comfort, convenience and health of our people; the increased number of great public and private enterprises directed by engineers, have been contemporary with the improvements in engineering education. Indeed achievements in engineering education, resulting in an ever more competent profession, has in no small measure been respon-

sible for the economic and social progress of this country. Engineering is a peculiar profesion. It ranges over a broader and far more diverse spectrum of future employment than any other profession. This makes the professional education of its future members an unusually complex and difficult matter.

It is believed that the important conclusions from any objective appraisal of engineering education over the past century will indicate that its achievements have been real and significant; the changing requirements of the profession have been anticipated and met; those engaged in engineering education have been alert to needs required by circumstance and science, and finally, that as in any forward moving profession, problems of change and adjustment are clamoring for solution in the new period of transition before us. These will be solved by the collaboration of all elements of the profession as other problems have been resolved in the past.

Reserve this date . . . .

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ANNUAL MEETING

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The Technical Institute: Its Relation to Engineering Education and Trade Training*

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Periodically and with increasing frequency the Technical Institute type of education under one name or another comes to the fore as a topic of discussion. It is my plan to give some of the background of the Technical Institute in its current form and acceptance, to discuss the Technical Institute as we find it and try to evaluate some of the influences and trends that may give us a clue as to where this particular type of education is going.

Nature of the Technical Institute

There seems to be a more general agreement on the major elements in a description of the Technical Institute than there is at the moment on terms commonly used for this type of education. A 1931 report of the Society for Promotion of Engineering Education entitled "A Study of Technical Institutes" strongly advocates the use of this term. The influence of this report at least within engineering education and engineering has been a tremendous one. When the Engineers Council for Professional Development set up an accrediting committee and procedures for Technical Institutes, much of the Technical Institute concept detailed in the 1931 report carried over to the accrediting procedure.

The Engineers Council for Professional Development publishes in its annual report a detailed statement or definition of the type of curricula included within its accrediting procedure. Because this statement is so important to engineering and engineering education it is quoted completely as follows:

"Curricula to be considered are technological in nature and lie in the post-high school area. They differ in content and purpose from those of the vocational school on one hand and from those of the engineering college on the other. Curricula in this field are offered by a variety of institutions and cover a considerable range as to duration and content of subject matter, but have in common the following purposes and characteristics:

1. "The purpose is to prepare individuals for various technical positions or lines of activity encompassed within the field of engineering, but the scope of the programs is more limited than that required to prepare a person for a career as a professional engineer.
2. "Programs of instruction are essentially technological in nature, based upon principles of science and include sufficient post-secondary school mathematics to provide the tools to accomplish the technical objectives of the curricula.
3. "Emphasis is placed upon the use of rational processes in the principal fundamental portions of the curricula that fulfill the stated objectives and purposes.
4. "Programs of instruction are briefer, and usually more completely technical in content than professional cur-

* Presented at the Centennial of Engineering, September 4, 1952, Chicago, Ill.

ricula, though they are concerned with the same general fields of industry and engineering. They do not lead to the baccalaureate degree in engineering. Such designations as Engineering Aide, Technical Aide, Associate in Engineering, and Engineering Associate are appropriate designations to be conferred upon the graduates of programs of technical institute type.

5. "Training for artisanship is not included within the scope of education of technical institute type."

The ancestry of many points in the above policy can be recognized in the SPEE report. In addition the Office of Education Bulletin No. 228 entitled "Vocational Technical Training for Industrial Occupations" presents a non-engineering description of the Technical Institute type of program.

The Technical Institute program lies in an easily recognized area between vocational training on the one hand and professional engineering on the other. At the same time it is difficult to define specific limits which automatically classify a program in one area or the other. The Technical Institute programs are essentially vocational. So too are engineering and other professional programs which are essentially vocational in their ultimate objective.

An outstanding characteristic of the translation of the major objectives of the Technical Institute training programs is the freedom which educational institutions have exercised in developing curricula and operating procedures. Technical Institute programs are characterized by the strong influence of the objectives for which they are designed. These programs differ one from another in length of training period, the proportion of technical work, and the types of instruction that are used.

Admission requirements, at least for that group of Technical Institutes accrediting by ECPD, are not too different from those for four year engineering curricula. Perhaps less stress is laid upon formal high school education through a recognition that maturity and experience may substitute for high school graduation.

Technical Institute programs are geared to meet the needs of both full time and part time pre-employment training. Specific groups of courses to meet training needs of persons employed in industry are commonly offered as part time evening programs.

The Technical Institute is commonly described as a terminal program. In this sense it means that the graduate is trained for immediate employment in a relatively restricted activity. It certainly does not mean that the Technical Institute graduate is disqualified from continuing his education into the areas of professional engineering. Many have done so successfully.

The distinction between the Technical Institute program and one of vocational training of less than college grade is more readily discernible. The Technical Institute training pays little attention to training in skills. Rather it emphasizes the "why" through adequate study of college level mathematics, chemistry, and physics. The latter technical courses familiarize the student with the applications in industry of these fundamental sciences.

It is becoming easier to recognize the desirable resources of a teacher of technical subjects within a Technical Institute curriculum allied to engineering. In addition to an adequate scientific and professional background the teacher in the Technical Institute must rely upon knowledge gained in practical industrial experience and the application of his technical "know how" to the needs of industry. The Technical Institute teacher frequently enrolls in his classes many persons who are currently employed and whose job experience is considerable. An important aspect of the teacher is his ability to deal with adults in a way that will command mutual respect in the classroom.

Historical Development

The first Technical Institutes in the United States were organized about 125 years ago with somewhat the same objectives though vastly different curricula than we find today. The early needs for technical training arose from the situations in a pioneer country with expanding agriculture and industry. Another instance of the trend toward "practical" training is in the enactment of the Morrill Land Grant Act about ninety years ago.

It was logical that the colleges should undertake the development of technical training. They had existed for a long time, had developed a heritage of prestige, and had the advantage of granting degrees to label their graduates.

Many early Technical Institutes have had long and proud careers. On the other hand a considerable group of schools that started as Technical Institutes abandoned their objectives to become conventional four year engineering colleges. Questions of prestige of the degree, the nomenclature of a college, and the pressure of alumni seem to overbalance the advantages of the struggle for a successful Technical Institute.

The Engineering Science Management War Training Programs sponsored by the United States Office of Education during World War II were essentially a Technical Institute type of training. Many engineering schools introduced programs through the ESMWT procedures and financial support and retained them as post-war Technical Institute curricula.

Present Status of Technical Institute Instruction

The needs for increasing technical education have developed Technical Institute curricula in schools with varied backgrounds. The annual survey prepared by Professor Leo Smith of the Rochester Institute of Technology and published in the Technical Education News classifies Technical Institutes in the following categories and with the corresponding enrollments for 1951–52.

Maritime Academy and Federal Schools	715
State and Municipal Technical Institutes	16,155
Privately Endowed Technical Institutes	11,140
Extension Divisions of Colleges and Universities	7,435
Proprietary Technical Institutes	10,290
YMCA Schools	682
Total	46,417

The above enrollments do not recognize the work done in the junior and community colleges in Technical Institute type of curricula. The junior or community colleges are becoming increasingly important factors in post secondary education especially in certain areas of the far west and of the southwest. The community college must be reckoned with in forecasting the total contributions of the Technical Institute type of training.

The ECPD accrediting program recognizes only those curricula that lie in fields parallel to recognized curricula for engineering instruction.

Need for Technical Institute Training

The current needs for personnel trained in a Technical Institute arise partly from the present shortage of engineers. More fundamentally they are the result of a number of factors that exist in the technological age in which we are living. The United States census shows that an enormous increase in the production of goods and services has been accomplished without a substantial increase in the percentage of the population engaged in gainful employment. Simultaneously a steadily growing proportion of young persons up to 24 years of age are not engaged in gainful employment but are enrolled in schools or colleges.

Production and services are requiring increasing percentages of skilled and semi-skilled employees. Manufactured products are becoming more complex, industrial establishments are larger, and the coordination of their various elements more complicated. A knowledge of how

to handle things is no longer sufficient while knowing how to handle people and ideas is becoming relatively more important.

It is now an accepted fact that for a period of years the engineering schools will be turning out far fewer engineers than are needed in industry. Coincidental with fewer graduations is a stepped up tempo of industrial production which in itself increases the demand for engineers. How many engineers can be absorbed by industry is problematical but surveys indicate that industrial needs are at least twice the number of available graduates.

Most certainly some shortages can be alleviated if fully trained engineers are placed only on jobs that require an engineer's training. It has been customary, probably for very good reasons, to use engineers through a training period on assignments which can be handled by persons with less theoretical training. It is here that the technician, however he may be called, can best make his contribution toward increasing industrial productivity. Surveys from one source or another indicate that industry analyzes its own program and concludes that it can use from two to six Technical Institute graduates for each graduate of a four year program.

Opportunities for technical training strictly within industry are limited in most instances to the acquisition of specific skills and knowledge. Industry is requiring, to an increasing degree, that new employees shall report with fairly well developed specialities backed up by basic training in fundamentals that will increase the ultimate capacity of the employee beyond what was formerly demanded of him.

These factors are general ones and exert their influence on other types of education than the Technical Institute. It is worth recognizing however that the increasing emphasis on technical training, the shortage of engineers, and the trends in education are emphasizing the Technical Institute. Those who plan Technical Institute programs recognize that the needs of industry can be met only through a variety of offerings.

Strengths of the Technical Institute

Professional engineers through their societies and through their industrial employers are exerting a strong influence on the determination of the Technical Institute program within fields allied to engineering. The Engineers Council for Professional Development, representing the engineering professions, has through its accrediting committee set a pattern which requires a high standard of performance.

The Technical Institute has an important element of strength in that it prepares for specific employment assignments with relatively short well integrated educational programs. They are varied in nature because they are specifically designed to meet industrial needs. They prepare young men adequately for their immediate needs and for their ultimate growth into jobs of increasing responsibility.

Because Technical Institute programs are shorter they represent less investment in both time and money between high school graduation and employment in industry. The cost of tuition is small as compared to the availability of young men for technical employment two or three years earlier than if they entered industry as graduate engineers.

The ultimate success of the Technical Institute type of training lies in the individual success of the graduates. These young men enter industry with a training in fundamentals and their application to industrial situations which places them in a position of knowing "why" as well as knowing "how".

Looking Ahead

Every industrial and educational survey dealing with the Technical Institute type of education points to the increasing need for its acceptance in industry, in education, and by the engineering professions. This definitely fixes certain responsibilities.

Additional institutions that can qualify through staff and experience in technical education have opportunities to broaden their resources through Technical Institute curricula. By direct cooperation with industry it is possible to plan short curricula to meet the needs of the increased numbers of youth who are completing secondary schools and who must have further technical training before entering industry.

Technical Institute curricula should present a balance between training for technical competence and that which will enable graduates to deal effectively with people and ideas and to gain an appreciation of social values and responsibilities. Such programs are neither competitive with nor antagnostic to existing vocational programs and professional engineering. Proper coordination of the Technical Institute program with other types of education increase the effectiveness of all of them.

The higher institution which engages in Technical Institute training in addition to the more conventional degree training and research must realize that the Technical Institute program is different in objective and plan of operation but is not necessarily thereby higher or lower in educational values than either vocational or professional training.

The engineering profession ably supported by licensing requirements reserves for itself those levels of professional activity which require the peculiar type of training which the engineer receives in college. While the engineer seeks to multiply his capacities for handling the highest levels of professional competence he must be aware that he can increase his own productivity by assigning responsibilities for many technical assignments to those with less training than a full engineering curriculum. It is the responsibility of the engineer therefore to guide and direct the sub-professional type of training and the sub-professional technician in order that the engineer may be increasingly useful in his professional capacity.

Both the engineering profession and institutions of higher learning jointly share a responsibility to promote greater public and professional recognition of the Technical Institute type of education.

Industrial employers are still beset with the belief that the standard recognition of a post high school training is a degree. Much must be done by pioneers within industry to sell the idea that the Technical Institute graduate playes a useful and important role in industrial organizations. The graduate of the Technical Institute needs recognition in his own right because his competence while differing from that of an engineer is as necessary and perhaps just as important.

Summary

There are many indications that technical training has arrived at a point where the needs of industrial and other aspects of technological development can be more nearly met through an increased emphasis on the Technical Institute type of education. The movement has many elements of strength. Well developed Technical Institutes of many different kinds are acquiring status in education, industry and the engineering profession. There are no basic problems which will prevent the development of the Technical Institute movement. How fast the institute type of training will grow depends upon the acceptance of its potential contribution to our economic achievements.

The Engineer and the Scientist*

By W. F. G. SWANN

Director of the Bartol Research Foundation of the Franklin Institute and Senior Advisor for the Franklin Institute Laboratories for Research and Development

In the company of those representatives of what man has achieved since the birth of civilization stand several hoary-headed patriarchs. There is painting, an old fellow so rich in years that even civilization itself does not cover the span of his life. Apart from a few bizarre distortions of his normal physiognomy representative of modern art, he seems very much as he was 500 years ago. There stands architecture, who reached his zenith when most of the modern world was peopled by beings not far removed from savages. There stands sculpture, at the peak of its perfection two thousand years ago. There stands literature, grown to full maturity in the time of the Caesars. There stands music, younger, it is true, than its companions in art, but old enough to have acquired traditions stemming well into the past.

And in this ancient and dignified company there stands a representative who is little more than a child in years. He is indeed an infant prodigy by the standards of age of his fellows, a prodigy whose brilliance seems to stagger the imagination of all around him. In the last 150 years of his life, he seems to have accomplished in his own field more than has been accomplished by all the hoary-headed representatives of man's genius from time immemorial and indeed 90 per cent of his achievements are products of the last half century. This prodigy, whose name is Science, can be excused if, in looking around him, he does so with a patronizing air and a feeling that if all who are in his company would do things as he does them all would be better done.

In his advice as to procedures this child, Science, speaks in great detail, and as I study his precepts I become alarmed at the ignorance of my forefathers. I feel that there is nothing that they could do which I should not be able to do better. I know quite a little about mechanics and machinery. I know quite a little about the laws governing the workings of things. I know quite a little about how to design things so that they shall behave as I expect them to behave, and I shudder to think of the time when what I know was not known. And then, I receive rather a jolt to my complacency. I look at one of Michelangelo's masterpieces in Rome, and as I gaze at the great dome of St. Peter's I am conscious of a certain fear lest some spirit, conscious of my arrogance, should come to me and say: "Swann, I am commissioned to order you to build another dome like that, with such modifications as will insure that it is not a straight copy." A chill of fear comes over me for I am conscious of the fact that the dome I build will probably fall down. I beg my visiting spirit to wait while I consult an engineer who is skilled in these matters, but be denies me this privilege and says: "No, my friend, you must build it with the knowledge you have. Did not I find your mind, a moment or so ago, comparing its knowledge with that of Michelangelo? Did you not tell yourself that

*Address at Centennial of Engineering, Chicago, Illinois, Sept. 4, 1952, founded upon material presented by the author in *Physics Today*, June, 1951.

even when you were quite a young man you knew more about statics, about the theory of elasticity, about dynamics and about mathematics than was ever known to Michelangelo, and were you not assuring yourself that unless a man knew these things he could not design even a simple building so that it would be secure against catastrophe. It was only when you turned out of the narrow street in which you had been walking and saw Michelangelo's masterpiece that you became a little confused as to your reasoning. No, my friend, my orders are that you should build that dome with the knowledge that you have. After all, do you not know much more than Michelangelo knew about the very things which are concerned in the erection of that structure?" But as the responsibility is forced upon me, my fears grow and I beg the spirit to allow me to talk with somebody. "Perhaps," says my tormentor, "you would like to consult with Michelangelo. Shall I call him forth from the grave for an appointment?" And then as, in bewilderment, I turn to look upon this spirit, I find him looking at me with a humorous smile as he says: "My friend, go your way. You are excused from building the cathedral. After all, the time has not yet come for its visitors to be sent so suddenly to heaven."

And so I departed in some humiliation to meditate upon this comparison of my knowledge with that of the great mediaeval architect.

Acoustics

In order to restore my morale, I decided that before I was commanded again to undertake such a dangerous task as building a cathedral, I would attempt something on a smaller scale, where a little accident here and there would not be so catastrophic. And so I thought of acoustics, for after all the nature of sound is quite well understood. I can work out neat mathematical problems about sound. I can do all sorts of stunts with Fourier series and with differential equation and the like, stunts which would have flabbergasted old Michelangelo. In seeking a focus for my abilities in this matter, I came upon an old violinist who was highly skilled in his art, but knew nothing about science. In fact, after a few words with him, I found that he knew no more about acoustics than did Michelangelo. I said to him: "My friend, I have been watching you play that instrument and I think that I may be able to tell you how to play it better, for I am a student of acoustics and know all about the laws of sound. With my knowledge and your skill, I am sure it should be possible to play the violin better than you play it." "Very well," said the old violinist, "here is the violin—play it." "Oh, please," I said, "not so fast. I wish to start with something much more fundamental. Indeed, I do not know that I wish to use that instrument at all. It seems to me a very stupid instrument, with no scientific background It is strung with a cat's inside and played with a horse's tail. It has a form dictated by no scientific principles and the only information I have been able to find with regard to it is to the effect that the form had something to do with the supposed figure of the Virgin Mary. I would like to study a very simple case first." And so, I proceeded to suspend a simple stretched string between two fixed points in space and to discuss all the various modes of vibration. I explained how the frequency of vibration determines the pitch, how the overtones determine the quality and so forth. The old violinist, much impressed, but much bewildered, said: "All right, here is the bow; now let us play it." On drawing the bow across the string, the old violinist heard nothing, for we all know that a string so mounted would emit practically no sound at all. The old violinist complained that he could not hear anything, but I felt that it was very unreasonable of him to insist upon what, it seems, is the relatively minor matter of hearing something and proceeded to argue that it is much better to understand what you do not hear than to hear what you do not understand. But the old violinist seemed sad about this

matter and went away, a little comforted, however, by the fact that although he may not know what he is doing he knows how to do it.

Start With Simplified Problem

It is characteristic of the ways of the scientific attack to take a simplified problem, and, by studying it thoroughly, hope that one may proceed to understand and control the complex problem. In the field where the man of science has had the matter in hand from the beginning, this procedure has been very successful. Thus, he started with pure academic interest to inquire why electricity was emitted from hot wires in a vacuum. From the experiments of this epoch certain interesting laws developed which incited further research and further experiments. Some of the phenomena were born more or less in isolation and by themselves presented no great individual prospects. However, they were brought together by the man of science, who nurtured their development, watched over their progress, marshalled them from time to time into more efficient groups as regards their potentialities, until finally we have in the world of today, radio, television, and a hundred other things whose operations, if viewed for the first time, would seem so complicated, so unrelated, and so miraculous that no brain would have the courage to interpret them. If we could imagine some super-genius of the inventor kind who, by a rule of thumb and horse sense—it would have to be a very special kind of a horse—had arrived where we have arrived today in the science of electronics, but without knowledge of the basic fundamentals pertaining to the subject, and if this genius presented us with the various pieces of equipment, with sales bulletins telling us how to turn on the switches and manipulate the knobs, we would have a marvelous time for a week; but even if the apparatus continued to function longer, I venture to say that we should have a terrible task if anything went wrong with it, and further improvement in its operation would take place very slowly indeed, if at all.

Now unfortunately the man of practical affairs has not the opportunity, so frequently afforded to the man of pure science, of choosing his own battleground or even the antagonists with whom he will contend. The man of science fashions his weapons and invents them to his liking. Then he seeks an enemy against whom he may use them with the greatest efficiency. Sometimes when victory has been attained, the territory conquered is rather barren, but he may care little for this if the fight has been a good one. Sometimes the acquired territory is rich in values of many kinds, in which case the inventor receives much kudos for the benefits he has brought to mankind. He is given credit for having unselfishly worked for the good of his fellows. Alas, I fear that in this matter there is a good deal of hypocrisy. In 90 per cent of the cases he has worked on the job because he liked the job, as Richard Coeur de Lion fought the Saracens, not so much for holy motives, as for the reason that to him war was the meat and drink of his existence. If the researcher should find that the future gave utilitarian value to his discoveries, he would probably be as surprised as anyone else at such a consummation of his efforts.

As I have said, the practical man has not the opportunity of choosing his territory for the battle, and those who support him are not willing to look far into the future and hazard the belief that what he does today may be of great value then, even if it has no value now. The practical man has to meet the problems as they come to him. Even if some kind spirit should reveal to him the ultimate fundamentals at the back of his problems, it might not be practicable to find the solution for his immediate task by tracing the story from the fundamentals to the end point. Even though the problem might be one of no perplexity in the sense that the train of relationships could be visualized, it might be one of great complexity, so that its solution was not

realizable within the limits of the skill of man.

If I tap this table, I feel that I understand the fundamentals which control the nature of its oscillations. I can write down the differential equations which govern the whole story and whose solution, subject to the appropriate boundary conditions, would represent the last word in the problem. Alas, however, it is probable that in this particular case the solution would be attended by such difficulties of mathematical complication, that no mathematician who had ever lived could solve it. The problem is one of no perplexity but of staggering complexity.

And so it behooves the practical man of science, the engineer, to adopt procedures less ambitious than those of the man of pure science; and as a consequence, there come into being empirical relationships which experiment reveals to represent truths and which could presumably be deduced from more fundamental starting-points if one only had the knowledge and skill to carry out the process. When so deduced, it would frequently appear that the empirical relations are approximations, but approximations so good that nothing better is necessary for the practical end point. One of the reasons for difficulty in relating the empirical rules to the ultimate fundamentals is the fact that those fundamentals have frequently no power to suggest that the things which are neglected in the approximation are really negligible, for they have to be prepared to deal equally well with other problems in which they are not negligible, even though no such problem should present itself among those concerned in the affairs of our universe.

Fundamental Principles

In any domain of scientific knowledge, we are concerned with the basic fundamental principles, which usually take the form of differential equations, and the solutions of problems governed by those principles. The physicist is apt to place the solutions in a role subordinate to the fundamentals. This is a questionable procedure, for the solutions are in a sense richer in law content than are the fundamentals. The fundamentals apply to all solutions and therefore dare not emphasize the special features of any particular solution. Thus, to take an example, the fundamental laws of acoustics, supplemented by recognition of the psychological significances of pitch, quality, etc., govern the course of all sounds which are produced. They govern the course of acoustical phenomena involved in the production of Beethoven's Fifth Symphony and they also govern the acoustical phenomena involved in the singing of "Old Man River" but they have no more power to demand one in preference to the other. Now the musician is very much interested in which composition is being played. Moreover, when he has his compositions, he starts to invent new laws relating to the compositions themselves. He starts to invent laws of harmony and counterpoint. The fundamental laws of wave motion, basic to acoustics, have no objection to our musician's laws of harmony and to what he tells his pupils as to how the compositions should be played, but they take no part in demanding these laws and give the musician no help in his task of formulating them. These laws are laws characteristic of the group of *solutions* of the fundamental laws, the solutions in which the musician happens to be interested. Indeed, I suppose a pure acoustician who was asked to present a concert would demand that a blackboard be placed upon the stage. On the blackboard he would write the differential equations controlling acoustical vibrations. He would turn to the audience and say: "There, my friends, you have it all! Everything that has ever been composed and everything that ever will be composed! I hope you enjoy it! Good evening."

Now the engineer, as distinct from the pure physicist, is a little bit like the musician. He is very interested in the particular problem itself and in the re-

lation of one problem to another. He senses relationships applicable to the particular solutions, which relationships he may very well formulate as laws. The mathematical physicist may be a little annoyed at this and inform him that his various laws are not independent. "Do you mean," says the engineer, "that you can deduce all of them from one of them?" "Oh no," says the mathematician, "they are neither independent, nor will any set of them completely define the remainder. From my standpoint, they are an abominable logical mess." "But," says the engineer, "are they not all right?" "Oh, they may be all correct," saws the mathematician, "but they are like a lot of ill-dressed people. The hat of one belongs to the coat of the other, the shirt of one belongs to the collar of another. They are awful." Now the engineer does not worry so much about this, provided that his laws are of use. He does as much as he can by discovering valuable relations among the various things which he studies and combines these relations here and there, using everything he can get hold of to help him, even the pure mathematics and logic of the mathematician, when he can, and he seeks, with this rather heterogeneous combination of paraphernalia to accomplish what he sets out to accomplish.

And so, in meditating upon our ancient and mediaeval architects, I have to believe that, though unconscious of the general fundamental laws, they nevertheless sensed many things which were true and were able to mould them into a frame of procedure which was sufficiently concrete and self-consistent to serve as a guide in their operations. *We* should feel very insecure in this frame, fearing that something had been forgotten, unless we could see the elements of that frame as consistent parts of the more complete whole.

Seek Better Understanding

The man of science frequently finds himself seeking for a better *understanding* of the law with which he deals. Now this concept of understanding possesses the potentiality of breeding many illusions. I could talk for some hours on this matter, but one example will have to suffice.

In my student and early teaching days, it was the custom to seek an explanation of everything upon a purely dynamical basis. It is true that dynamics itself, at the period of its birth, was not a science which appealed immediately to the intuitions of the scholars of that time. A description of motion in terms of the activities of supernatural beings who carried things about in a manner determined by God was something which appealed much more strongly to the intuitions of the day. However, the collosal achievements of Newton and his successors grew a kind of reality into these dynamical concepts, a reality which, as time went by, became stronger and stronger, so that in the latter half of the last century there were many who felt that so-called dynamical principles represented the ultimate basis of understanding and were themselves fundamental in their claim to be understood without appeal to anything else. He who did not feel in his bones that dynamics was unassailable and obvious in its meaning was an ass, or at best a kind of lunatic devoid of the fundamentals of common sense.

The matter is illustrated by a comment in Sir Arthur Schuster's "Theory of Optics," written as late as 1904, and it must be remembered that Schuster was one of the world's high priests of natural philosophy in that epoch. He writes: "The study of physics must be based on a knowledge of mechanics, and the problem of light will only be solved when we have discovered the mechanical properties of the ether." Writing in another place of Maxwell's equations, he remarks: "The fact that this evasive school of philosophy has received some countenance from the writings of Heinrich Hertz renders it all the more necessary that it should be treated seriously and resisted strenuously."

And so, in my student and early teaching days, it was the custom, following the lead of Maxwell himself and his school, to seek an explanation of electrodynamic phenomena on purely dynamical bases. If we wanted to make somebody understand a circuit with self-induction, capacity and resistance, we would refer to a ball vibrating in a viscous fluid at the end of a spring. We would say: "Now the self-induction in this circuit is like that mass on the end of the spring. This capacity is like that spring. The electrical resistance of the wire is analogous to the viscous resistance of the liquid, and so forth." By thinking of the spring and ball, which we of the older generation felt we understood more or less, we endeavored to accommodate our thinking so as to understand the electrical problem. Today all of this appears to be changed. At an early age youngsters start to play with radios and to acquire quite a little knowledge concerned with the essentials of their operation. This fact has reversed the whole situation as regards reality in the mind of youth, and the youngster of today and the older youngsters who are doing research in our laboratories seek to understand dynamics by showing that it is like electrodynamics. And if the youngster wishes to understand how a ball bobs up and down on the end of a spring when immersed in oil, his teacher is apt to say: "Now this weight is just like that inductance in one of your radio circuits. The spring is like the capacity, the viscous resistance of the fluid is like the resistance of the wire. Now you know that the electrical circuit will oscillate; and in a similar kind of way, the ball and spring oscillate. You know that if the electrical circuit is stimulated by an external force of frequency equal to its own, it will resonate and build up a big amplitude; and for exactly similar reasons, the ball on the end of the spring builds up an amplitude when subjected to an external force which harmonizes with the system in frequency." Thus, since you understand all about the nature of the electrical oscillations of the circuit, you ought to be able to stimulate your brains to the point of understanding why and how a ball bobs up and down on the end of a spring in oil."

No longer does the engineer seek to understand his electrical problems through mechanical ones, but when he gets a mechanical problem, the first thing he does is to seek the electrical analogue and think in terms of that—he seeks the equivalent electrical circuit. And so this concept, reality, is indeed like a chameleon, changing its color to harmonize with the setting of its time.

If I were asked to distinguish as far as possible in a few words between the state of mind of the pure physicist and the engineer, I would, summarizing what I have said earlier, claim that the high spot of the interest of the physicist is the understanding of the relation between the various parts of his science in terms of the minimum number of hypotheses or starting points. If he is a very sophisticated physicist, he will realize that probably no set of starting points has any prior claim to fundamentality other than is implied in this potentiality of representing the minimum of starting points. To the physicist, a good set of laws provides the means through which, by saying few things, many consequences may result. Sometimes the physicist is not so interested in tracing out the consequences of his laws, but the consequences represent the main interest of the engineer and sometimes the consequences themselves, with their interrelations, can form a scheme for the deduction of further useful consequences without very much appeal to the fundamentals. This wide knowledge of the consequences of the fundamental laws can grow a sensitivity to the way things happen and can grow it even in the mind of him who is unacquainted with the fundamental laws. This sensitivity, developed to a high degree, provides what we may call intuition. And so, in meditating upon our ancient and mediaeval architects, I have to believe that, though unconscious of the general fundamental laws, they never-

theless, on the basis of hundreds of years of experience, sensed many things which were true and these they were able to mould into a frame of procedure sufficiently concrete and self-consistent to serve as a guide to their operations.

As distinct from the procedure of the conventional man of science, and farther to the left, as it were, than the engineer, we find the inventor. Frequently the inventor is very hazy as regards the fundamental principles which control the phenomena with which he deals, but he enjoys a certain compensation by the utilization of knowledge of an enormous number of experimental facts and processes which he combines in all sorts of ways in search of the end he desires. There is apt to be a high mortality in the expected achievements; but valuable end products frequently appear, even when, in the light of a strict appraisal of affairs as represented by the scientific knowledge of the day, it would seem that they never should have appeared.

Engineer Stands Half Way

The engineer stands half way between the pure scientist and the inventor. He is not so concerned with harmony of relationships leading back to the simplest form of fundamentals, but he is concerned with the reasons for things in terms of empirical relations, etc., which he uses to guide his thinking. The inventor is for the most part conscious of these relationships only through a strong sensitivity to their results.

The inventor walks in the territory which the man of science has mapped out into regions of assured fertility, dubious fertility, and almost certain sterility. The man of science, and indeed the engineer, are inclined to conserve their efforts by walking in the rather limited realm which, on the basis of the laws with which they operate, represent regions of assured fertility. However, the inventor walks with courage everywhere. He sees a pasture which he thinks has promise. The physicist would explain to him that his reasons for expecting something from that region are invalid, and in 90 per cent of the cases they are, but the inventor walks nevertheless. He walks persistently, so that every now and again he finds some spot which is rich in content, not perhaps for the reasons that he expected, but for other reasons of which he may be only partially conscious. If we should trace his own reasons to their origin, they might constitute a set of heterogeneous associations with no very obvious logical connection, but which, through the scheme of profound regularity inherent in nature, had conspired to give a suggestion which was fruitful in spite of the very dubious foundations upon which the suggestion was made.

There was a celebrated inventor whose employees hung upon the walls of his laboratory a placard which stated as follows: "The poor fool didn't know enough to know that it couldn't be done, so he went ahead and did it."

In seeking to understand the relationship between phenomena as we meet them without an appeal to fundamentals, much use is made, particularly by the engineer, of analogy. Indeed, Maxwell's electrodynamic scheme, as already cited, had as its object the setting up of an exact analogy between dynamics and the science of electricity and magnetism. Frequently, however, analogies take the form of approximations, but when the approximations are established, the practical man rapidly grows intuitions which become sharpened with time and develops, for the realm of the analogy, a set of laws which are self-contained even though their relation to the fundamentals may be hidden.

One has an example of this in matters pertaining to electrical circuits where, provided that the wave length of any oscillations concerned in the circuits is long compared with the dimensions of the circuit, we can think in terms of a certain type of simplification. There grow the concepts of capacity, inductance, impedance, to which the practical engineer, stimulated perhaps by rivalry with the medical profession, feels the urge to add

another number of godforsaken words, such as admittance, transconductance, etc. While seeking to stimulate my sarcasm in this connection, I have thought of a new term "abuttance." I present it to the radio engineers in the hope that they will find a meaning for it. At present it is like the doctor's discovery of a "cure" for which there is no disease.

In terms of the simplified laws, the practical man proceeds to manipulate these various quantities and to become very clever at predicting what will happen in this case and in that. Occasionally, however, situations arise in which the simplified laws no longer are adequate. The practical man does something about this by making some kind of correction as far as possible in the language of his old formulation. As knowledge advances, however, more and more of such cases arise and the patches on the patched up framework become more obvious than the framework itself.

Engineer Must Acquire New and Strange Tools

As more and more of the fruit of nature's richness becomes plucked, more and more of the potentialities of empiricism, founded upon the structure of matter in bulk, become exhausted, and the more do we have to look to the sub-grained atomic and nuclear structure of matter for further progress. This necessity of an appeal to fundamentals has made itself obvious in electronics, where, however, these sub-grained matters have made their appearance with such subtlety that even the practical man has become inveigled into thinking in terms of them and to walking in a territory which would have filled him with fright if he had been thrown into it all at once. And now, these sub-grained matters are invading other realms, the realms of metallurgy, where new things about the strength of materials, the nature of friction, etc., are only capable of being understood in terms of laws about atoms and molecules and laws, moreover, involving ideas born of such relatively abstract things as the quantum theory of atomic structure. The time is coming when the engineer will find that the sharpening of his old tools is not sufficient for his task. He must acquire new and strange tools, tools which seem antagonistic to his common sense. But common sense is a curious attribute. In its proper domain, it is a jewel of priceless value, but when strongly entrenched in any realm, it can impede progress. Fortunately, it is a changeable kind of thing, and it will happen in the future, as it has happened in the past, that the common sense of the past is the nonsense of today, and the apparent nonsense of today is the common sense of the future. It is for the young engineers, or at least for those of them who are concerned with some of the most interesting aspects of future developments, to attune themselves to the common sense which is to come, that they may walk with the same security under its guidance as their predecessors have walked under the guidance of the common sense of their day.

National Science Foundation News

Edward McHugh, director of the Division of Research and Industrial Service, has announced that the **National Science Foundation** has made a grant of $10,200 to **Clarkson College of Technology** to sponsor research on "Mass Transfer Coefficients and Interfacial Areas in Packed Columns."

James H. McMillen has joined the staff of the **National Science Foundation** as a member of the physics staff of the Division of Mathematical, Physical and Engineering Sciences. He comes to the Foundation from the **Naval Ordnance Laboratory**, where he was chief of the Hyperballistics Division.

Looking Ahead in Engineering Education*

By L. M. K. BOELTER

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Looking ahead in Engineering Education is indeed a precarious undertaking. The existence of a temporal region of experience from which a rational extrapolation may be made is postulated. To this end the author has relied heavily on the historical data presented in the reports of the American Society for Engineering Education (1). Evidence of lag in effectuating ideas of engineering leaders and of cyclic repetition (probably of period equal to a generation) as well as the lack of the application of the experimental method to pedagogical procedures and to curricular changes may be found in the literature, including college catalogs.

Again, the earlier lack of acceptance of Engineering in the universities of the United States † has left vestigial scars and other effects which are manifested in the academic organizational structures and academic attitudes. The establishment of the Land-Grant Colleges and the early Institutes of Technology had a salutary effect upon the position of Engineering in the Higher Educational Structure of the United States.

The first works of Engineering rest in antiquity. The works of Engineering and Architecture can hardly be separated at the beginning. The great accomplishments of the ancients shall not be recounted here but it will be observed that the progenitor of the Modern Professional Engineer was not always required to conserve national resources or to practice economy. On the other hand, he had much less power available to perform the assigned tasks. Again the early engineer expended a goodly amount of energy developing engines of war.

The transmission of knowledge in the early days was either through shrewd observations of the existing engineering works or through the master-pupil relationship, although certain records were maintained also.

The first American engineering curricula (1) may be characterized as applied science containing a liberal core of sociohumanistic studies. Shop courses were introduced fairly early and remained in one form or another in many curricula for at least two generations. Engineering laboratory instruction was also begun early in the period of the germination of engineering instruction, approximately 1870.

Throughout the succeeding years a gap grew between the sciences (Physics and Chemistry particularly) and their application in the Engineering courses and in the profession. Engineering curricula could no longer be characterized as applied science. Rather, Engineering emerged as a science in its own right and in addition great stress was laid upon the art of Engineering. But the bases upon which Engineering Instruction were built did not change with the change in philosophy and content of the Physical Sciences. Thus a gap of approximately one generation developed between knowledge as added to the Sciences and its application in Industry, which gap was reduced to several years during World War II.

* Presented on September 4, 1952 at the Centennial of Engineering, Symposium on Engineering Education and Training, Chicago, Illinois.

† The same phenomenon was exhibited in Germany (2).

Parenthetically, developments in the Physical Sciences have, however, resulted in the creation of new Engineering Curricula. This gap between the formulated and experimental knowledge of the Physical Sciences and the content of engineering courses and the application to the design of Engineering systems cannot again be allowed to develop.

Segments of the Physical Sciences may be neglected in the Science Departments; these areas must be assumed by Engineering but their assumption should not prevent the transmission of new knowledge of the Physical Sciences into Engineering.

Unterstützungen of the Curriculum

The four-year professional undergraduate curriculum is still considered to be a standard and has proven satisfactory.* However, supports for the curriculum, quintuple in number, will be developed so that the four-year curriculum will remain "a unique segment" of Engineering education.

1. A considerable body of opinion now exists to the effect that at least two years can be substracted from the pre-college school experience (3) of a student who has the intellectual capacity for college work and who also possesses the necessary physical stamina. In other words, the same material now presented can be compressed into a lesser time or the equivalent of two years of appropriate work may be added between the kindergarten and high school graduation. Canadian and European experience will aid to point the way.

The subject material to be introduced in the two years saved will receive careful attention. The University of Chicago in the University College has studied intimately the recasting of knowledge (4), the emphasis on particular modes of reasoning, and desirable methods of instruction (5).

2. The work-study program (often formalized and called the cooperative program) deserves much more thoughtful attention and support. With a slight change in the college calendar and scheduling of all required courses each term, students may be given the opportunity of industrial employment of technical level commensurate with their maturity, training and education. Briefly, an industrial (or governmental) organization will set aside one job which either two, three, or four students will serve seriatim each year depending upon the college calendar. The undergraduate professional curriculum demands the support of this program for survival.

3. The Engineering profession will encourage and develop an internship program to begin directly after the award of the Baccalaureate. Certain industrial organizations have made great strides in post-graduate study for their employees for instance see (6). But the profession has not yet effectively and formally recognized a post-bachelor's program for the training and education of a professional engineer. NOTE: The Engineering Societies require a certain number of years of "in responsible charge" and certain State Laws require that engineers-in-training serve under registered professional engineers.

The College of Engineering, the Employer, and the Engineer-in-training (or Junior Engineering) acting in concert would, in the following tentatively presented plan, arrange an individual program consisting of part or of all the following components:

a) On-the-job employee instruction by supervisors.
b) On-the-job self study.
c) On-the-job courses.
d) Off-the-job courses, socio-humanistic and technical.
e) Off-the-job self study.

The program will be designed to aid the engineer-in-training to achieve professional status, to insure more effective performance of the job assignments during the training program and to fill such gaps in general knowledge and specific applica-

* Certain Colleges of Engineering maintain 5 year curricula at the present time, for example, Cornell University.

tions as will allow the most effective discharge of his duties as a citizen.

An examination or/and a dissertation based upon the total training and educational experiences of the candidate for the previously selected period (say four to five years) will climax this internship program. The initiation of this program at an early date is imperative to the future well-being and strength of the profession.

4. The post-graduate education of the engineer-in-training and that of the professional engineer will receive attention through an intensified adult education program, sponsored by Engineering Extension. Technical courses designed to (a) broaden the engineer, (b) specialize his experiences and general courses designed to give depth and meaning to his contributions to society will be available. Correspondence courses designed to meet specific needs will be had more generally. Techniques will be designed to aid the engineer who is located in out-of-the-way places both domestic and foreign. Publications of the Engineering Societies will be utilized to increase the pertinence of the post-graduate educational experience.

5. Finally a dynamic graduate program leading to either Science or Engineering degrees is in a virile growth stage. Graduate work in Engineering assumed a master-pupil relationship in its early days with emphasis on the original individual investigation. Accompanying its growth will come a recognition that a change of method of instruction is necessary. Courses are now replacing seminars, instructors are undertaking the direction of many research projects; the result in many instances has been that graduate work either has become an image of undergraduate instruction or has retained the master-pupil relationship but on a larger scale and in either case the effectiveness of the instructional methods must be examined.

Graduate students may wish to obtain a foundation which will allow them to practice the Engineering of Tomorrow for which a knowledge of the modern concepts in the Physical and Life Sciences is essential. Others may wish to broaden their base in engineering while still others may wish to specialize in a branch or phase of engineering. Combinations of the three objectives, although resulting in dilution, are also a possibility.

As graduate work in engineering becomes an accepted part of the training and education of the professional engineer the present dichotomy will be resolved through the development of two paths toward advanced degrees.

The M.S. and Ph.D. degrees (or their equivalent) will be directed toward the discipline of research, with emphasis upon the techniques of analysis and with the subject objectives either chosen to decrease the gap between the Physical and Life Sciences and Engineering or selected to broaden the student's background in engineering. In summary, this graduate experience may be designated as existing in the area of Engineering Science.

The other stem, clearly a professional stem, leading to the degrees Master of Engineering and Doctor of Engineering will be directed to the discipline of the design of engineering systems with emphasis on the techniques of synthesis and with objectives of either broadening or deepening the student's background in engineering. This graduate experience may be designated as existing in Engineering as an Art strongly supported by Engineering Science.

In both paths (the word curriculum is avoided in designating graduate work) the methodology of engineering will be employed and a greater emphasis will be placed on its socio-humanistic content. Other professional groups, for instance, medicine at one University, are now administering these two graduate programs seriatim with the professional sequence coming first.

Graduate programs designed for full-time professional employees have been in existence for many years (General Electric—Union College, Westinghouse—University of Pittsburgh, for example) and are now quite common (6). However,

Purdue University has established a unified M.S. program which will serve as a guide for off-campus programs (other examples of off-campus programs are Ohio State University, University of Maryland, University of California) as well as for a study of the unified curriculum concept (7).

Engineering as a Profession

More practicing engineers are now clearly concerned with the content, significance and responsibility of the profession (8) than was true in the past, however; see Waddell & Harrington in reference (9) for evidence of the activity and concern in the 'teens. Two events have contributed to this favorable climate. The present shortage of engineers has caused the professional engineers * to resurvey the position of the profession locally and nationally as he presents the facts to school counselors and to prospective engineering students.

Again the registration procedure in many States requires the evaluation of the professional experience of the candidate and the examination which is set is designed to evaluate the professional capabilities of the candidate. These forces require concentrated attention to the question of the status of the profession.

Thus the ethical, aesthetic, cultural, economic and technical content of engineering is evolving and the methodology implicit in the practice of the profession is slowly emerging.

Increased professional consciousness will reflect itself in the curricula. With time there will be greater emphasis on Engineering in contrast with emphasis on a specialty or branch. This changed attitude is and will be revealed in the philosophy of engineering instruction. The greater appreciation of the unity of knowledge (10) will influence both the profession and the curricula. For instance, systems analysis (or systems engineering or operations analysis) will become an essential portion of the climactic segment of the curriculum. Less attention will be paid to individual courses, their number will be reduced (22, p. 14), but more attention will be given to the thoroughness and content of individual courses and their articulation with other courses. The academic experiences of the student will be planned and executed as a part of an activity beginning in the 8th (or 9th) grades and extending to achievement of professional status some fifteen years later. This period will include the high school years, the four year engineering curriculum and industrial experience; between the undergraduate curriculum and the beginning of the industrial employment certain individuals may also include graduate work.

* The excellent work of ECPD, EJC, ASEE, and Local Engineering Councils is noted.

Technical Institutes

In the organization of an Engineering Department in industry, a variety of talents and training is needed. The profession will in the future vigorously support the development of training programs for those groups which form a part of the organizational structure of the professional engineer. Other professional groups have and are taking leadership in assuming responsibility for the training of contributing groups.

If properly organized the leadership of the Engineering Department in an industrial unit should reside in a professional engineer. A fraction of the group will be professional engineers, another segment will be engineers-in-training. But still another segment consists of those who have completed a two-year program (Technical Institute type) or equivalent (1, Vol. II, p. 11 and (11)). Some years ago many four-year engineering students withdrew during the first two or three years of a college curriculum. Was this abbreviated experience the optimum desirable for the semi-professional? Is there not a better way of training these young men?

Technical Institute type programs have been introduced in many sections of the country as an answer to the above ques-

tion, for instance, by Pennsylvania State College, Purdue University, in the junior colleges of California, in New York State, and in private, including proprietary, schools. Broadly speaking, the courses of these programs should not rest on formal physics and chemistry and mathematics courses beyond high school. Physical systems are described verbally and numerically. Numerical methods of analysis are used. Students learn about particular systems. Physical and chemical principles are taught and illustrated in connection with the system or apparatus under consideration. Arithmetic methods are introduced as needed. Verbal description and analysis replace symbolic description and analysis, the former augmented through pictorial means (drawings and sketches). Activities ancillary to engineering such as time-keeping, scheduling, etc., as related to the system or apparatus or job, are taught in terms of the system under consideration.

Pre-engineering courses do not suffice for this program. Imaginative guidance is needed and can be contributed by professional engineers, educators and teachers.

A four-year program including the equivalent of two years of general education (humanities, economics, accounting, language, literature, history) and two years of technical institute work as described above and closely integrated will fulfill a need for a man with a college training who will work with and assist the professional engineer.

Alternatively a four-year program including general education courses and certain of the science and applied science courses (partially equivalent to but not identical with engineering science courses) deserves consideration as a training regime for others who will work with and aid the professional engineer or who intend to enter engineering curricula for further study.

Flow of Information

As an educational center the engineering college is a component in a flow circuit. Knowledge flows outward through the undergraduate student, the graduate student, faculty consultation, faculty texts, and technical publications. The channels consisting of the newspaper, house organ, radio and television have not been exploited adequately. However, within the next generation the professional engineer will utilize more effectively these media of communication.

But the return flow path from industry and from the field to the engineering school has not been established as a conscious effort. Catalogs, advertisements, house organs, sectioned and working models, often available to the faculty and student, serve as a partial return path only.

A function of industry is to utilize knowledge, which process will generate further knowledge; in sum, the function of utilization results in the generation and diffusion and differentiation of knowledge. This information must flow back to the college where it should be formulated, integrated and generalized. Still further fragmentation of knowledge by the engineering college will be considered indefensible (10, 22, p. 37). Herein lies a research task, appealing to the imaginative instructor, which the engineering school will accept in parallel with the projects now in being (12).

A word will be included relative to the recording of engineering works. The product is the final record of an engineering design. Buildings, bridges, television sets, gas turbines contemporaneously exemplify the application of the engineering methodology to the satisfaction of the needs of man. But the idea upon being reduced to practice has also been committed to paper through drawings, designs, specifications, etc. A record of these engineering works may reach engineering publications and textbooks in part and very late. The time lag between discoveries and their general use can and will be reduced by increasing the breadth and effectiveness of repositories of engineering knowledge and the assumption by the engineering college of a new role in the

return path in the flow circuit of engineering knowledge.

Industrial Functions

Industrial functions (13) of import to the engineer often cited are design, research, development, production, construction, sales, service, maintenance and others. But these functions have not yet been carefully defined. For instance, what are the disciplines of the design function? Does a universal design methodology exist? The attention of professional engineers and of teachers will be directed to the problem of establishing the meaning of the design function and to develop its methodology.

Again the existing experimental data will be sifted and further data will be gathered in order that the production (14) and construction functions (and others) may be placed upon an analytical basis. Herein lies one of the greatest challenges to Engineering Educators.

The Curriculum

In this "outlook" little will be said about the undergraduate curriculum. Some of the elements of a curriculum are presented in references (15) (16) (17) (18) (19, Appendix VI) (20). Considerable thought has resulted in a tentative formulation of the content of the engineering curriculum, of engineering methodology and of the disciplines underlying engineering (18 and 24). Place has been found in modern curricula for the presentation of the analytical plus the experimental modes of solution and for the science as well as for the art of engineering.

A clarion call for the return of certain social-humanistic studies to the engineering curriculum (24) and their recognition as a stem paralleling the technical stem has refocussed attention on the trend toward the specialization (in this case the exclusion of non-technical engineering courses) which appears to be part and parcel of the "natural" evolution of curricula in the modern American college.

The effect of specialization and fragmentation of knowledge, a resultant of scholarship devoted to the rational extension of knowledge, upon courses, curricula, and instructor attitudes has been examined within the last two years with the conclusion that both general education and the discipline of synthesis (building or assembling in contrast with analysis) suffer in present curricular arrangements and teaching methods (21).

The social-humanistic content of the engineering curriculum will find its expression as an integral part of the totality of student experiences rather than in separate compartments or courses. The process of integration of Engineering, discovering the disciplines of the several branches, and establishing those disciplines which are common to Engineering will also automatically include the requisite elements of knowledge referred to as the social-humanistic (25). One of the great unifying forces in engineering education will prove to be a rational inclusive treatment of the properties of materials; the proper use of materials is the cornerstone of engineering practice. On the other hand, that segment of the student's education designed to equip him to meet the social and intellectual requirements of society (above and beyond his professional competence) will serve as another unifying force.

General Education

The goals of a total education have been listed by Day (26) as (A) to arouse interests, (B) to develop skills, (C) to convey knowledge, (D) to establish the import of understanding and appreciation, (E) to establish attitudes and ideals, and (F) to cultivate habits. The portion of the total education (consisting of the effect of the environment on man and his reaction) which may be considered as general education is defined by Hook (21, p. 311) as "the study of certain essential areas of knowledge together with the acquisition of certain basic skills which should be required of all students. These requirements should meet the needs of all human beings both as participating mem-

bers of the community and as individuals who must undergo basic life experiences, irrespective of their future vocation."

The portion of total education and general education which is now included in each 4 year engineering curriculum will need to be established explicitly. Total and general education goals will be formulated. The social-humanistic content of the curriculum will thus acquire more meaning and greater significance. The way is being illuminated by several colleges in the United States, such as, for example, the Carnegie Institute of Technology (15). The Engineers Council for Professional Development has progressed in this area and will continue its excellent work in cooperation with professional education groups.

Teaching

Methods of instruction and teaching techniques (19, 23) are receiving much attention, especially through the support of the American Society for Engineering Education. The introduction of the summer school for engineering teachers (1, Vol. II) was a great step forward but a return to the conception of breadth, rather than attention to detail, will characterize future activities of this type. The new vehicles of communication (recordings, films, radio, television) will each be tried and tested by engineering teachers during the coming years. The application of the experimental results obtained through a study of the several methods and techniques will represent a milestone in pedagogy.

Summary

In summary, the curriculum will be based upon principles of transfer of knowledge and of skills, upon the inculcation of a consciously formulated methodology, utilizing examples for incentive, continuity, and temporal pertinence, resting the illustrations upon natural (physical and life) phenomena, but with primary emphasis upon the phenomena themselves and their analytic formulation. Throughout the engineering educational process the complete growth of the student will be facilitated with the teacher as central (23). He will be encouraged to "know himself," to know others (and society), and to be a living example of the interrelationship between the physical and human worlds. For the student there cannot exist two stems (technical and social-humanistic) but rather a synthesis not only of the knowledge of the physical world but of knowledge itself (22, p. 58). In particular he will be given the opportunity to express himself orally (added to the present emphasis on written expression) and to give vent to creativeness—in other words, to "be himself." The student will feel that he is responding to an exciting stimulating experience which has great human implications and effects.

The author trusts that this "outlook" will contain both bases for action and stimuli for discussion. For only from free untrammelled unprejudiced rational discussion will the truth emerge. Each engineering school must find its own solution of the engineering student–faculty–industry relationship within a generally understood and agreed-upon framework.

Definitions

1. Engineering as an Art. In the application of ideal systems to the world-in-being many force fields are effective which are either unknown, cannot be analyzed, or, it may well prove, that analysis is too expensive. The knowledge of the professional engineer, based on scientific training but amplified by practical experience, fills the gap between the results of analysis and the behavior of the actual system. Often he does not employ mathematics beyond arithmetic as a language, his modes of expression being the native tongue and graphics (drawing), and his discipline is formal logic. He senses the magnitudes of variables which can neither be formulated nor evaluated by the scientist. Extrapolation from system to system with reasonable assurance of acceptable results with the details unknown is indeed hazardous; the exercise of this procedure accounts for the stature of the profes-

sional engineer. Briefly, he deals with a mass of unformulated knowledge.

2. Training is defined as the acquisition of knowledge and skills which are to be utilized in the solution of a particular problem or to be directed toward a particular end.

3. Education will be defined as the acquisition of knowledge and skills which are to be utilized to solve general problems or a range of problems such as are faced throughout a "full" life.

BIBLIOGRAPHY

1. WICKENDEN, W. E., "Report of the Investigation of Engineering Education 1923–1929," *Engineering Education*, Vol. I and Vol. II, Society for the Promotion of Engineering Education, Pittsburgh, Pennsylvania.
2. LILGE, FREDERIC, *The Abuse of Learning*, The Macmillan Co., New York, New York, 1948.
3. RUSSELL, JOHN D., *The American Educational System*, pp. 221–222, Houghton Mifflin, 1940.
4. COULTER, M. C., SMITH, Z. L., AND SCHWAB, J. J., "The Sciences Programs in the College of the University of Chicago"; reprinted from *Science in General Education*, E. J. McGrath (edited by), Wm. C. Brown Co., Dubuque, Iowa, 1948.

   NORTHROP, E. P., "Mathematics Program in the College of the University of Chicago," *American Mathematics Monthly*, Vol. LV, No. 1, January 1948.
5. AXELROD, J., BLOOM, B. S., GINSBURG, B. E., O'MEARA, W., AND WILLIAMS, J. C., Jr., "Teaching by Discussion in the College Program, A Report," *The College, University of Chicago*, January 1949.
6. LINDVILLE, L. M., AND MCEACHRON, K. B., JR., "Cooperative Engineering Education at Graduate Level from the Viewpoint of Industry," *Journal of Engineering Education*, Vol. 40, pp. 475–479, May 1950.
7. HOWLAND, W. E., AND HAWKINS, G. A., *Graduate Engineering Program of the U. S. Naval Ordinance Plant*, Purdue University, Lafayette, Indiana, 1951.
8. O'BRIEN, M. P., "The Nature of Engineering," *Journal of Engineering Education*, Vol. 41, No. 3, pp. 133–141, November 1950.
9. WADDELL & HARRINGTON, *Addresses to Engineering Students*, Waddell & Harrington, Kansas City, Missouri, 1911.
10. WYLIE, PHILLIP, "Impure Science," *Bulletin of the Atomic Scientists*, pp. 196–200, August 1951.
11. RODES, H. P., "Technical Training in the Junior College," *California Journal of Secondary Education*, January 1949.
12. BOELTER, L. M. K., "Engineering Research," *Mechanical Engineering*, p. 978, December 1948.
13. POTTER, A. A., "Whither Engineering?", *Mechanical Engineering*, p. 3, January 1934.
14. BOELTER, L. M. K., "Engineering in the Fabrication Industries," *Proceedings, Fourth Annual Industrial Engineering Institute*, p. 22, University of California, Los Angeles and Berkeley, California.
15. DOHERTY, R. E., *The Development of Professional Education*, Carnegie Press, Pittsburgh, Pennsylvania, 1950.
16. HOLLISTER, S. C., "Differentiating Characteristics of an Engineering Curriculum," *Journal of Engineering Education*, Vol. 40, pp. 291–294, January 1950.
17. SAVILLE, THORNDYKE, "Horizons in Engineering Education," *Journal of Engineering Education*, Vol. 39, No. 7, pp. 344–354, March 1949.
18. BOELTER, L. M. K., "The Design of an Undergraduate Engineering Curriculum," presented at the Semi-Annual Meeting of the American Society of Mechanical Engineers, San Francisco, California, June 30, 1949, and Chemical Engineering Division, 58th Annual Meeting of American Society of Engineering Education, Seattle, Washington, June 20, 1950; Published by the Chemical Engineering Division of the A.S.E.E., Northwestern University, Evanston, Illinois, 1951.
19. BOELTER, L. M. K., "A Discussion of Engineering Teaching," *Agricultural Engineering*, Vol. 28, No. 11, pp. 512–516, November 1947.
20. WALKER, ERIC, "Specific Objectives of Electrical Engineering Curricula," *Electrical Engineering*, Vol. 71, No. 6, pp. 514–518, June 1952.

21. LIVINGSTON & OTHERS, "The Problem of Specialization in Twentieth Century Education"—Mid-Century Convocation of the Massachusetts Institute of Technology—The Social Implications of Scientific Progress, Chapter VII, pp. 300–352, John Wiley & Sons, New York, New York, and the M.I.T. Press, Cambridge, Massachusetts, 1950.
22. WHITEHEAD, A. N., *The Aims of Education*, Mentor Books, New York, New York, 1949.
23. BARZUN, JACQUES, *Teacher in America*, Chapters 7 and 14, Little, Brown & Co., Boston, 1946.
24. HAMMOND, H. P., & OTHERS, "Report of Committee on Aims and Scope of Engineering Curricula," *Journal of Engineering Education*, Vol. 30, No. 7, pp. 555–556, March 1940.
HAMMOND, H. P., & OTHERS, "Report of Committee on Engineering Education After the War," *Journal of Engineering Education*, Vol. 34, No. 9, pp. 589–614, May 1944.
HAMMOND, H. P., & OTHERS, "Report of the Committee on Engineering Education After the War," *Journal of Engineering Education*, Vol. 35, No. 1, pp. 36–58, September 1944. (Summary)
HAMMOND, H. P., & OTHERS, "Report on Humanistic-Social Studies in Engineering Education," *Journal of Engineering Education*, Vol. 36, No. 5, pp. 338–351, January 1946.
25. BROWNELL, BAKER, "Are Engineers Educated?", *The College and the Community*, Chapter VI, pp. 67–75, Harper & Bros., New York, New York, 1952.
26. DAY, EDMUND E., "General Education in the Land-Grant Institutions," *Journal of Engineering Education*, Vol. 42, pp. 331–336, March 1952.

Sections and Branches

The **National Capitol Area Section** held its Fall Meeting, October 6, 1952, at Catholic University of America, Washington, D. C. Vice-President Boring's letter was read concerning the best-paper competition for younger members of the Society, and the method was described for conducting the competition within the Section.

Chairman L. K. Downing then introduced H. H. Armsby, the Section's representative on General Council, who reported on actions taken by Council at the Dartmouth Annual Meeting. Mr. Armsby also reported interestingly on the Centennial of Engineering in Chicago. Following introduction of M. S. Ojalvo, chairman of the Section's subcommittee of ASEE Young Engineering Teachers Committee, S. P. Schlesinger, former chairman of that subcommittee, stated objectives of the committee and reported on its recent activities. Recent Development in the International Field was the subject of an interesting talk by S. S. Steinberg, chairman of the International Relations Committee.

Chairman Downing stated the theme for the Section's 1952–53 meetings,—Improved Utilization of Engineering Manpower,—and introduced R. L. Goetzenberger who dealt with the following questions: "What are employers doing to make the most effective use of present short supply of engineering manpower? Are the engineering schools doing all they should to aid?" His talk stimulated a lively discussion.

Looking Ahead in Engineering Education

By S. C. HOLLISTER

Dean of Engineering, Cornell University

During the past eighty years *we have witnessed a change in this country from an essentially agrarian nation to one of industrial power.* It has come about chiefly through the introduction and utilization of technology. This basic change has had a profound effect upon the country's international position and upon its potentiality for moral and spiritual, as well as economic, leadership.

During the past fifty years the population of the country has doubled. Our production, however, has increased to four and three-quarters times what it was at the turn of the century. This has come about largely because we have been able to develop and apply, at the hand of the worker, about four and one-half times as much energy as was available to him in 1900.

Not only has the engineer made possible this increase in production; he has had profound influence upon transportation and communication as well. The world has shrunk in size in terms of the movement of goods and people. Every part of the world now may listen to every other part so that all may know the doings of any people as they occur.

Some of the earlier steps in our industrial development could be achieved with little more than native ingenuity. However, the introduction of engineering education in the country became increasingly effective; until now it is a necessity, both for the maintenance and the advancement of the technological system.

Since preparation by way of education always precedes the accomplishment, it follows that *the planning of engineering education requires an estimation of the future and its needs.* Today we are laying the groundwork for the accomplishments of twenty-five years hence. A look ahead, therefore, into the world of a quarter of century from now should furnish us some guiding principles upon which the future trends of engineering education should rest.

It is the engineer's lot to be called into situations in which there are serious problems. There are many serious problems confronting this country; solutions of which will have to be found in the relatively near future. Such problems tax the ingenuity and capacity of our profession.

A whole group of problems arises from economic sources. America has always plunged into full use of its natural resources with very little thought of what might occur after the sources have been exhausted. We have been depleting them at a terrific rate. We have said to ourselves that when these resources are gone others will surely be found to take their place. How these were to be found was left largely to yankee ingenuity and technical know-how. In many spots the time has now come when we must get busy developing the know-how to meet some of these basic problems.

From one source we learn that for every barrel of petroleum taken out of the ground two more barrels of petroleum have been found that were not known about before. From this it has been concluded that we have an inexhaustible supply of petroleum. All we have to do is to develop new means of detecting the petroleum that is not at present known about, and new means of producing and refining petroleum that is known about but is in such form that at least a considerable portion cannot readily be extracted by known

means at a reasonable economic cost. While some say we have an inexhaustible supply of petroleum we have, during the past decade, changed from an exporting to an importing country so far as this particular material is concerned. During that decade we have also turned the same corner with lumber, and the decade prior to the last, we turned the corner with zinc and copper. We are about to become a large importer of high-grade iron ore. Of course, tin, nickel, natural rubber, chromium, and most of our manganese have had to come from the outside, along with some of the lesser quantities of economically strategic materials.

It is expected that our population in the next twenty-five years will increase by twenty per cent. This will affect what is needed to maintain the basic economy at a reasonable level. We will in addition have continuing commitments abroad which must also be cared for, where in many places rising populations menace the economic balance.

In agriculture it is expected that the yield per acre by 1975 will have had to be increased over forty per cent. Some of this of course will have to come about by further engineering developments and some by new conceptions, new discoveries and new controls in plant science. The result in production, however, is that the number of people fed per farm worker must be increased in twenty-five years by forty per cent.

It is no news to people in many parts of the country that one of the critical materials now in short supply is water—water for irrigation, water for industrial uses, water for drinking purposes, water for navigation. Although the country has an enormous supply of water, it frequently is in the wrong place or occurs in the wrong season. Immense problems lie ahead in *meeting the water situation so that there may be redistribution, reclaiming of used water, and conversion of sea water into potable supply.* Unless any of this can be done at an economical cost, it is of course of no avail.

Another problem that faces the country is *the development of a sound policy and practice respecting our timber resources.* This has been a subject of active discussion for at least fifty years, but the problem is still with us and the engineer faces the need of further development for economical use of wood products, or an adequate substitute for a fair amount of the present supply.

We appear to have a very large supply of *coal.* One of the problems of this supply, however, is not whether there is ample quantity of coal of good quality, *but how it may be wrested from its present natural site and supplied at the point where it can be used effectively.* Possible conversion in the natural site to another form, such as gas, which may be removed and transported more easily than the original solid coal, is one possibility that has been worked upon to some extent. The amount of coal needed twenty-five years from now may conceivably be one hundred per cent in excess of the present production. It must be recalled that one means of covering the shortage of petroleum is by the synthetic manufacture of petroleum products from coal. It must also be recalled that petroleum is a raw product for the development of many chemicals; a use which is rapidly accelerating. This use is an addition to that of petroleum as fuel, and may eventually form a major portion of the demand upon coal, if the raw source is transferred to that material.

Another natural resource which is being consumed at a terrific rate is *natural gas.* The use of this fuel has increased threefold in the last fifteen years. Like petroleum, this form of fuel is being used extensively for fuel in its crude form. The day may not be far distant when the need of special products made from distillation will become critical. At such time we may regret the inefficient use of the material in its crude form, and its depletion to the point where the supply is below the required need in more effective form.

To a constantly increasing degree we are *utilizing electrical energy* in order to multiply the effectiveness of a man-hour of work. Most of our electrical energy is

available to us through the development of thermal power. Although some hydroelectric power may still be developed in the future, it will not form even one-quarter of the total source of electrical energy that will be needed in another twenty-five years. This is another way of saying that the major power expansion of the future will be through the development of further thermal power with its consequent demand upon coal, natural gas, and petroleum.

Whether in the field of materials or in the field of fuels, the ultimate goal is constantly to work toward the harnessing or utilization of supplies or materials or energy that are well nigh inexhaustible. For example, many products that are now waste might conceivably be converted into useful substances. Solar energy which is in some parts of the country in abundance around the calendar might some day be the source of energy that now depends upon the consumption of some of our priceless natural resources. The constant struggle towards this ultimate goal is a struggle which will set more and more men free throughout the world. The more general the occurrence of the base of our source of materials or power the more free will mankind become.

Thus far I have discussed largely the consequences of the need of our expanding economy because of the expansion in our population. There are other factors which place great burdens upon the engineering profession. Consider for a moment a continuing interational situation which maintains a high tax burden upon the citizens of the country. The tax burden, it is generally agreed, is about as high as it can well be short of all-out war. Put in another way, it means that each man has just about reached the saturation point of his buying power, because of the tax burden. If wages and prices go up together this of course does not increase the buying power, except during the transition stage. We cannot afford always to be in that transition stage. *The problem therefore is what we can do to give people greater services for the same amount of money.*

There are a great many things that need redesign in the interest of saving money. As an example, it is extremely difficult today for a young man, regardless of the field in which he is working, to acquire a home and a young family at the same time. The cost of present-day construction is forcing more and more people to undertake building their homes with their own hands. This is one form of answer to labor organizations that undertake to put artificial barriers in the way of necessities by actually demanding pay for no work. The economy in the past has supported a certain amount of boondoggling, but there is a limit to what people will stand after which checks and balances are developed by the consumer.

But housing is only one form of commodity, the cost of which is too high. Other appliances must be redesigned in order to be considerably simplified and reduced in cost. This would give an opportunity for the purchase of some other appliance that now cannot be afforded. For example, our automobiles are too highly priced. *We badly need a cheap car,* one that will furnish transportation with comfort but not luxury. We need cheaper radios, television sets, refrigerators, air-conditioners, washing machines and the like. In time they may come, but we need these things now.

The American people have learned to do many things the expensive way. We are going to have to learn to keep things simpler and still perform the essential functions. This calls for the highest form of skill in design of which the engineer may be capable. It is our present tendency to add gadgets on top of gadgets to the point where sheer accumulation is burdensome. *We need to learn how to live more simply, and as engineers we need to learn how to design more simply, so that we may have more.*

In no part of our present economy is it more essential that simplification be practiced than in the conduct of war. In a continuing emergency we have no place for the old theories of war which held that costs of materiel were no object so long as

we won the war. What we must now do is to conserve our resources and still be in the position to win a war. In fact, unless we do conserve our resources we may not win out, either in war or in peace.

There is still another area in which the state of our economy suggests much work for the engineer. With continually increasing mechanization we create more wealth with fewer actual man-hours of labor. Obviously this would bring about unemployment if it were not for the fact that new products may be made with the labor saved in the first operation. The result, heretofore, has been a continually expanding industrial organization.

Whether this can go on *ad infinitum* has not yet been ascertained in the world. Whether the system can be applied to countries which have a greater population per unit of area than we have has likewise not been determined. The engineer is being called upon to work out these theories, both at home and abroad, especially in countries with less fortunate living conditions than our own.

Without considering the pressures upon our economy developed through the need of support from us to other nations, or the need of continued military preparedness, it is already clear that the engineering problems that are piling up ahead of the profession are accumulating at a rate far greater than the rate of increase of population. In fact, the problems are appearing at a constantly increasing rate, and there is no end in sight.

I have reported in other places that we have now reached the point in the development of engineers where we may expect no percentage increase of engineers in terms of the total population. We thus find ourselves leveling off in terms of numbers of engineers as per cent of population, whereas the really tough problems accumulating before the profession are piling up at a rate far greater than the rate of population growth. This is another way of illustrating the point that *engineering services to the community at large are increasing per engineer available for such service.*

What effect has all of this upon engineering education? We may ask ourselves what it is we are now putting into the hands and heads of our students that will really be effective in dealing with the kind of problems that we have laid out before us. How have we strengthened the scientific and technical preparation which we are now asking our students to master?

It is very clear that we cannot delineate sharply the various techniques that will be in use twenty-five years or fifty years from now; but it is certain that the principles on which these technical developments will be based are principles which are now available in the basic sciences. *Our problem, then, is to strengthen the basic science content of our curricula.* The importance of this conclusion is emphasized when it is recalled that the problems now before us are tougher to solve than the problems that have been before us heretofore, and require a more fundamental approach.

Another approach to the total problem of engineering manpower is the realization that with the requirement of increased effectiveness of each engineer there must be a readjustment in order to reinforce the work of each engineer. *This calls for a supply of capable engineering aides.* The training of these technical aides in itself should be advanced beyond what has been in use in the past. *This suggests the possibility of modifying our educational system to provide for the development of the professional engineer at a higher level than heretofore, together with the development of technical aides also at a higher level of training than is at present customary.* It may well be that the pattern of professional schools in the future will involve a more extended program than we now have, supported by four-year programs which will be calculated to develop the sub-professional personnel. It is conceivable that all of these programs would be collegiate degree-granting programs but of different duration and resulting in different degrees. I am not at the moment dealing with graduate study as such, but

I am dealing with education of the great majority of engineers who will go out into practice in the profession.

It is obvious that we are looking toward a period in which the function of the engineer is going to be increasingly important in the area of economic and political affairs, as well as in technical progress. In the planning of our education of engineers we are not permitted to reduce the little time that is now being spent in *broadening the professional engineer's background of knowledge.* On the contrary, *it is essential that we extend this time to provide a richer education than we can at present give him.*

In all of the foregoing we see the great need for expanding our creative activities. Recently I read an article in which one of our leading industrialists argued that our natural resources were inexhaustible. He cited cases in which there was a present knowledge of large deposits and the hope that many more deposits could be added to these if we could improve our methods of exploration, discovery, extraction and processing. If we could do all these things then our natural resources would be inexhaustible. Apparently he did not readily recognize that the inexhaustibility that he was depending upon was largely the inexhaustible ingenuity of engineers.

It is this inexhaustibility of engineering resource that concerns us in engineering education. We as educators must address ourselves more assiduously to the *task of developing in our students their imaginative, creative ability to a higher level than we have achieved in the past.* In fact, much of our teaching methods have not been aimed at this objective.

I do not want to be interpreted as believing that imagination can be put, by teaching processes, into the head of someone who has no imaginative power. I do firmly believe, however, that imaginative, creative ability may be enhanced by teaching methods. I am sure also that in the world today and in the engineering profession creative talent is the greatest needed and the most highly prized.

Whether the engineering educators accomplish the goal of service to our profession in the form here suggested is not important. What *is* important, however, is that we address ourselves vigorously to the task of appraisal of the situation, and then of arriving at an adequate, equitable and effective program.

Sections and Branches

The fourteenth annual meeting of the **North Midwest Section** of ASEE was held October 3 and 4 at Iowa State College. The main event of the meeting was the Annual Dinner which was high-lighted by an address by Leonard J. Fletcher, Vice-President and Director of Community Relations, Caterpillar Tractor Company. He spoke on "The Answer Not Found in Books." The meeting was closed with a luncheon where the annual business meeting was held and L. O. Stewart, former Council Representative, reported to the section on "Society Affairs."

For the technical sessions two general and six departmental meetings were held. The topics for the general sessions were: "An Experiment in Education-Television"; and "Humanities for Engineering Students."

The next meeting of the Section is to be at Milwaukee, Wisconsin on October 9 and 10, 1953, with Marquette University as the host institution. Elected to serve as officers for the next year are: Chairman: A. B. Drought; Vice-Chairman: Chester Pratt; R. J. Panlener: Secretary-Treasurer; Council Representative: K. F. Wendt.

Since engineering is changing from an art to a science, it is natural that more engineers are called upon to assume the role of the scientist and to advance the frontiers of knowledge as well as to use that knowledge for the benefit of mankind. If this is true, then he should be educated as a scientist.

The following three papers were presented at the ECRC (ASEE) Centennial Conference under the Chairmanship of Eric Walker, Vice President of ASEE and Dean of Engineering, Pennsylvania State College, September 5, 1952. Dr. Furnas, in the first paper, extends the thesis that many of our engineers are indeed scientists and Dr. Ihrig shows how education in industry should be bent to this aim. Dr. Brown advances new ideas concerning the role of education in our colleges.

The Engineer-Scientist of Today by C. C. Furnas

The Modern Engineer Should be Educated as a Scientist

In Industry: by Harry K. Ihrig

In College: by Gordon Brown

The Engineer-Scientist of Today*

By C. C. FURNAS

Director, Cornell Aeronautical Laboratory, Buffalo, N. Y.

From testimony in various quarters and from observation, it would appear that the ideal engineer should be a handsome and well-groomed biological specimen, with costume and coiffure readily changeable at will, and on short notice, to fit the traditional appearance and characteristics of: a research scientist, a plant operator, a professional designer, a technical detective, a salesman, a plumber, a leader of field parties, a leader in public affairs, a sociologist, and a business man. It's quite an order.

In the simpler days when things could be readily categorized, the relations between character of knowledge required and activities pursued might have been summarized in some such fashion as:

The Skilled Craftsman specialized in "know how."
The Engineer dealt primarily in "know what."
The Scientist lived in the domain of "know why."

Now it seems that the engineer is expected not only to know "how," "what," and "why." For reasons of sociology and salesmanship, he is also expected to "know who." Truly he is to be all things to all people and the educational system is subject to criticism because it doesn't continuously turn out the desired, universally adaptable, marvelous product.

Even if someone did exist who knew all the answers to the problems generated by this multi-headed demand, he could hardly cover the field adequately in any finite period of time. Fortunately, however, the director of this symposium has simplified matters by ruling that the discussion shall be limited to the general theme: The Modern Engineer is a Scientist. This markedly narrows the field and promotes simplification, but even this restricted subject is tremenduously complex and probably no one (certainly not this speaker) knows any of the exact answers to the problems. But I shall attempt to make a few observations, for whatever they may be worth, within the frame of reference of the engineer as a scientist. Be it known, however, that I am not one who believes that all engineers should be in the "scientist" category, any more than that all physicians should be research experts. In all the professions there is a real necessity for a large proportion to be the more prosaic practitioners, and education and training is short-sighted which neglects this need.

Before proceeding with the discussion of the specific problem in hand, a brief survey of the make-up of the engineering profession is in order. At the present time there are about 400,000 engineers in the country with employment distribution roughly as follows: universities 9%; government 24%; industry 67% (reference—*Bureau of Labor Statistics Bulletin No. 968,* May 1949). Depending substantially on definition, somewhere between three-fourths and seven-eighths of all those who have received engineering education remain within the confines of the profession, if you include administrative and executive posts which are closely linked to technical organizations. (With a more strict definition of engi-

* Talk delivered at meeting of the Engineering College Research Council, Chicago, September 5, 1952.

neers, others have estimated that approximately 50% stay within the profession.) At the present time roughly 15% of all engineers are engaged in research and development (reference—Furnas, *Jour. Am. Soc. Eng. Ed.*, Sept. 1952 p. 24) and this category embraces the bulk of those who fall in the "scientist" type of activity.

In addition to the engineers who at any one time have the strong scientist tinge, there will probably be a number who are on their way up from the ranks. So, as a liberal estimate, some 25% of the individuals in the engineering profession are, or will be, those for which extensive, effective and profound scientific knowledge and understanding is a necessity. A most important and necessary 25% it is, but in considering education and training let us not fall into the dangerous error of producing all Chiefs and no Indians.

Focussing attention on the select 25% (those in research, development, and new, constructive design) we find that there are some real problems in keeping up with the game, and probably some serious defects in the educational system. The situation was probably best summarized yesterday by Dr. W. F. G. Swann, at another symposium of this Centennial, when he said "The time is coming when the engineer will find that the sharpening of his old tools is not sufficient for the task." It is a sage and worthy observation. The situation will bear careful analysis.

Trends in Engineering

At the risk of appearing to be in my dotage and perhaps of being guilty of erroneous conclusions, I would like to list some observations on the trend of affairs in the engineering activities associated with research, development and design over the past 25 years. These come from the vantage point of practice, teaching, and administration of research and development, and from exposure to two distinctly different fields: (a) chemical engineering, and (b) aeronautics:

(1) Practical engineering problems have steadily become larger, more complex and more sophisticated.

(2) There has been a progressive trend away from straight empiricism and toward designing exactly and with confidence. In the chemical industry, pilot plants are sometimes omitted and in the mechanical and electrical fields much of the inventing is done on the drawing board.

(3) The use of theoretical considerations has increased a great deal in approaching new problems. This has been especially marked since the rise of the computer art which makes it possible to arrive at solutions of a multitude of synthetic problems, quickly. Computers are also rapidly becoming a basic research tool for fundamental scientists.

(4) Despite the decay of empiricism, laboratories have greatly increased in number, size and scope. In the applied research and engineering fields they are largely used to: (a) get quantitative information for design purposes and (b) proof-test prototypes or components, and (c) work out final design improvements.

(5) The "team" approach to most engineering problems predominates, which tends to throw the very best engineers onto one side or the other of administrative problems, despite all efforts to avoid them.

Characteristics of Successful Engineers

Matched against the above list of changing characteristics of the task, I would like to record some observations of the characteristics of individuals who have proven successful in the fields and activities with which I have been in contact. Perhaps my sample is not sufficiently large to serve as a basis for generalizations, but it does involve close acquaintance with at least several hundred individuals. As I have observed them, the principal characteristics of the successful engineers, a la scientists, are:

(1) They have high IQ's.

(2) They apparently have had *good*

undergraduate scientific training, but no particular colleges or universities seem to dominate as alma maters.

(3) They appear to have true scientific understanding. They really grasp the implications of $F = ma$.

(4) They may come from any part of of the country. They can come from any part of the world, but usually the European-trained scientist or engineer is less adaptable than the American-trained one. This is independent of any language barriers.

(5) They have drive, imagination and tenacity and at least reasonable judgment. They are not always, however, eager beavers or highly energetic people. Some are very leisurely and a few even appear, superficially, to be lazy.

(6) In the applied research and development activities those with engineering schooling appear to be in the majority but there are many with training as physicists, chemists, and mathematicians. This seems to come about as a result of the team approach to problems.

(7) Though there is a larger proportion of graduate degrees than in the routine phases of engineering, graduate degrees appear to be no requisite for success. A Ph.D. degree seems to help but it is no guarantee of success and no safeguard against sterility.

(8) More often than not they are poor salesmen and somewhat less than social successes. Whether they succeed in spite of or because of this, I am not prepared to guess.

(9) The most outstanding and most important characteristic in common is that they are *always acquiring* or *developing* new mental tools, by self study, improvising new tricks of scientific approach, exchanges of ideas with colleagues, or by formal course work.

As an appendix to these observations, it should be noted that many engineers and scientists get into and prove very effective in administrative and executive positions without having had any outstanding accomplishments as scientists or engineers. The brain trust boys—particularly the asocial ones—frequently bridle and grumble at this, but it goes on happening just the same.

What do the members of the polyglot collection of scientific engineers do which distinguishes them from the garden variety of engineers on the one hand and from the true scientists on the other? The principal and unique characteristics of their activities would appear to be two:

(1) They deal with items that are new, as distinct from minor modifications of already existing devices, processes or systems. This removes them from the routine engineering categories.

(2) Their objective is not to acquire knowledge for knowledge's sake (however interesting and intriguing that may be) but to produce some thing new, useful and usable. This sets their activity outside the pale of "pure" science tradition. Scientific knowledge is the most essential tool of their operation, but not the end object.

Examples

Examples of the work of the sophisticated school of engineering are easy to find. They involve the work of many people of many interests and background, but they all call for the skilled mind of the engineer (whatever may have been his academic background) who knows and uses new scientific tools within the frame of reference of engineering application. Some of the examples to be cited represent past or very recent successes. Others are items that are still "in work" and practical success is not yet assured. A few samples:

(1) Chemical Syntheses
   (a) The development and use of nylon—probably the top example of a truly new, entirely synthetic, specific material for mass use
   (b) The large series of aromatic compounds from the straight

chain, or aliphatic, materials of petroleum recently announced by the Carbide and Carbon Chemical Corporation

(2) Pharmaceuticals
  (a) The mass production of penicillin and other mold-generated specifics
  (b) The semi-synthesis and production of cortisone

(3) Electronic Devices
  (a) Modern television
  (b) Radar
  (c) The proximity fuse

(4) Communications Systems
  (a) The coaxial cable
  (b) Ultra high-frequency radio

(5) Nucleonics
  (a) The atomic bomb
  (b) Production of tracer materials

(6) Power Devices
  (a) Atomic stationary power plants
  (b) Atomic propulsion of ships and aircraft
  (c) Jet propulsion and other applications of the gas turbine
  (d) Ram jet engines
  (e) Liquid rocket motors

(7) Control Systems
  (a) Automatic navigation and autopilot systems for aircraft
  (b) Guidance systems for guided missiles
  (c) Industrial power control systems
  (d) Automatic control systems for complicated chemical syntheses

(8) Metallurgy
  (a) The production and use of titanium and its alloys
  (b) The production and use of ceramels (combinations of ceramics and metals for high temperature work)

(9) Computers
  (a) As used in gunfire and guided missile control systems
  (b) As used in flight simulators to work out aircraft flight problems and for training

(10) Aeronautics
  (a) Development of successful helicopters
  (b) Development of supersonic airplanes and guided missiles

Anyone can quarrel with the incompleteness of the above list, but it is only intended to be a small sample. He can also quarrel with the classifications or groupings, but one of the characteristics of modern developments is that they refuse to be simple, or confine themselves to single, rigid categories. The primary characteristic of the above items is that, in no case, were (or are) the answers to the key problems to be found in then-existing hand books. Seldom were the complete answers to be found in even the latest literature of pure science. The marshalling and integration of all available knowledge was required and frequently the discovery of substantial blocks of new basic information was necessary. It is the engineer (whether his academic handle says he is one or not) who pushes these items through to successful conclusion. It is fairly evident he cannot escape being a good scientist, too.

Teamwork Necessary

The second major characteristic of all items in the list is that success of the project was dependent on the work and talents of many individuals. In no case in the list could the scientific and engineering man-power requirement for a particular project be numbered in less than hundreds. In most cases, thousands were necessary; hence, the inevitability of large teams, with their attendant administration problems, in modern engineering projects. So despite my best efforts to confine my observation to that type of engineer who must be a scientific individual, I find myself coming full circle and saying that this rare and valuable individual must still be imbedded in a complex sociological matrix.

We now come to the crux of the discussion—the question: So What? Though I will admit that it is highly unsports-

manshiplike, I'm going to renege on attempting to answer that, for the two speakers who follow have that pleasant task, as representatives of education and of industry. Before turning the matter over to them I would, however, like to point out two almost self-evident facts:

(1) The education of the engineer, a la scientist, must continue throughout his entire professional life.
(2) Both educational institutions and industry have, not only an interest, but a duty to perform, in this pattern of never-ending education.

College Notes

J. H. Potter of the **University of Illinois** and T. Stephen Crawford of the **University of Rhode Island** have been granted leaves of absence to participate in the E. I. du Pont de Nemours and Company program "A-Year-in-Industry" for engineering educators.

Joseph V. Foa, head of the Propulsion Branch of the Cornell Aeronautical Laboratory at Buffalo, has joined the faculty of **Rensselaer Polytechnic Institute.** He has been appointed a professor in the Department of Aeronautical Engineering and will do research and teaching in the theory and application of jet propulsion and combustion.

W. R. Van Voorhis of **Fenn College** has been appointed Visiting Professor of Engineering Administration at **Case Institute of Technology**; he is also a member of the Case Operations Research Group.

Two major grants amounting to $1,000,000 by The Ford Foundation to the **Massachusetts Institute of Technology** for the support of research in the newly established Center for International Studies have been announced by President James R. Killian, Jr.

Construction started on Nov. 17 on a new engineering building at the **University of Wichita.** The building, which will house offices, classrooms and drafting rooms for the school's five engineering departments, will be completed in time for use in the fall of 1953, according to present plans.

John M. Russ was appointed Head of the Department of Engineering Drawing at the **State University of Iowa,** replacing F. G. Higbee, who has retired. Higbee will continue to serve the University on a part-time basis. M. L. Betterley was appointed Associate Professor in the same department.

By action of the Board of Trustees, H. Russell Beatty has been named Acting Dean of **Pratt Institute's** School of Engineering, replacing Nelson S. Hibshman, who is resigning to accept the position of Assistant Secretary of the **American Institute of Electrical Engineers.**

The nations's first graduate School of Industrial Administration at **Carnegie Institute of Technology** was dedicated recently. The featured speaker at the formal dedication ceremonies was Sidney A. Swensrud of the Gulf Oil Corporation. Carnegie's graduate School of Industrial Administration, founded in 1949 by a six-million dollar gift from the W. L. and May T. Melon Foundation, aims to provide young men with potential for leadership, fundamental training in management and engineering, and in responsibility for citizenship.

The Modern Engineer Should be Educated as a Scientist. I. In Industry

By HARRY K. IHRIG

Vice President in Charge of Research, Allis-Chalmers Manufacturing Company

Introduction

In the last forty years industry has changed more perhaps than in the previous hundred years, yet it has been reported [1] that in most engineering colleges the curricula in at least civil, mechanical, mining and electrical power engineering have not changed materially in that time. Since engineers are trained primarily for industry, it would seem that with the revolutionary changes going on which make industrial processes more scientific and more highly technical, the engineering courses should have been changed to adapt them to industry's needs.

The census figures show that in 1900 one graduate engineer was hired for each 250 workmen in industry. In 1950 one graduate engineer was employed for each 52 workmen and industry was asking for many more.

Taggart in a recent article [2] has said "Engineering education today is like a crazy quilt of somber wools and gaudy shoddy, chain-stitched on an academic assembly line, and sold at ever mounting prices to inexperienced youths for lifetime use. Each engineering school offers a half-dozen or so patterns with essentially the same skimpy wool content. Sales appeal is in the color of the shoddy, denoted by the hopeful adjectives chemical, civil and the like. This article is argument for an all-wool product made by slow, careful handwork. Bluntly it proposes a thorough four-year undergraduate drill in fundamental science and general engineering empirics, leavened by continuing study of the third of the engineer's troubles: Man."

This discussion is limited to the technical portions of the engineer's training.

Preindustrial Training

Since industry has become so complex and because it is continually changing, it is imperative that the engineer be trained in the fundamentals of science rather than the specific "practical" courses of any one industry. In fact, industry today with its indoctrination courses will train engineers with the most modern equipment and pay them well while so doing. Isn't this preferable to the student to taking up time in the engineering school trying to learn such subjects on equipment that is often obsolete.

None of the thousands of engineers on atomic energy projects could possibly have had specific courses in this particular field. Yet many physicists, chemists and engineers were able to adapt their fundamental training to this entirely new field. The only way an engineer can adapt himself to the new things developed after he has finished his formal training is to have his training embrace enough fundamental science so that he is able to make new applications of that science whenever necessary.

[1] Thorndike Savilk, "Engineering Education in a Changing World," *Journal of the American Society of Engineering Education*, Vol. 41, p. 4, 1950–51.

[2] Arthur F. Taggert, "Education for Engineering," *Mining Engineering*, Vol. 4, No. 8, p. 770–774, August 1952.

Augustine B. Kelley in a recent article[3] shows that the engineer is essential in the highly mechanized coal industry in the United States. Because of its mechanization our coal industry produces about four times as much coal per man as the next best producer. Also in the utilization of coal in such applications as the coal burning gas turbine highly scientific engineers are necessary.

In the oil industry science is used from geophysical prospecting to the synthesis and rearrangement of hydrocarbons to obtain the maximum antiknock properties in gasolines. The recent development of petrochemicals has opened up a whole new field for the application of physics and chemistry in the engineering of these products.

Allis-Chalmers Manufacturing Company makes about 1600 different items from tractors to hydraulic turbines. No possible engineering course could cover the specific manufacture of half of these. Yet all of them are based fundamentally on physics and chemistry with mathematics as the shorthand for expressing chemical and physical facts.

Engineering Training in Industry

Industry has not assumed that the universities have trained engineers in its specialized procedures. But it would like to be able to assume that the engineer has had a broad fundamental training so that he can adapt himself to industry's special needs. To this end industry has set up various training methods. The larger companies have formal courses, and the smaller ones depend more on personal instruction by older engineers.

A well known example of training supported by industry is the Institute of Paper Chemistry at Appleton, Wisconsin. In addition to paper technology, science courses are given and graduate degrees are conferred. The graduates of this course have made very good records in the paper industry.

The Humble Oil and Refining Company has courses of graduate level given by outstanding engineers and scientists from universities, who are invited to participate in this program by giving lectures and seminars in their various specialties.

Courses in reactor technology are given engineers from industry at Oak Ridge. This training gives them the proper background for the design of equipment to be built by industry for the Atomic Energy Commission, and for the eventual use of atomic energy by private industry.

In many cities, universities give evening courses for engineers in industrial plants. For example in Milwaukee, the University of Wisconsin gives graduate courses in Mechanical, Chemical Metallurgical, and Electrical Engineering. Research work for the master's thesis is done in the plants where the engineers are employed. During the last academic year 170 graduate students were enrolled. The enrollment for graduate work leading to the master's degree has steadily increased.

The courses are taught by regular faculty men from the College of Engineering at Madison. The student registers in and receives his degree from the Graduate School of the University of Wisconsin exactly the same as if he were in residence there. This enables an engineer to work full time and obtain a master's degree in two or three years by taking his graduate courses in the evening and doing his research work in the Company's laboratories or plants.

A University Cooperating Committee of the Wisconsin Society of Professional Engineers composed of engineers from industry has studied many of the engineer's problems. The writer has been a member of this committee for a number of years.

The Technical Institute was studied to determine its place in the educational and industrial engineering fields. It was recommended that the Technical Institutes be encouraged to train men for specific jobs to aid engineers in industry. This

[3] Augustine B. Kelley "The Engineer—Key to Coal Progress," *American Engineer*, p. 7–10, August 1952.

training should be given in technical institutes not directly connected with the University. The courses should be specialized and terminal in nature and should not be accepted for credit in the engineering college of the University. The function of the technical institute graduate is to do what might be termed sub-engineering jobs so that engineers may be used only for professional work. One of the best ways to alleviate the shortage of engineers is to use them for only truly engineering functions in industry. The technical institute graduate can thus release engineers for the real work for which they have been trained.

The medical profession for many years has used nurses, X-ray technicians, therapists, and other sub-professional help to aid the physician and hence free him to direct the medical program.

The University Cooperating Committee next studied a course in fundamentals for non-specialized engineering training and it was decided that such a course was very desirable from the industrial standpoint. A course was recommended which would consist approximately of:

Mathematics	28 credits
Chemistry	26 credits
Physics	33 credits
Engineering Fundamentals	33 credits
Humanities	24 credits
Total	144 credits

This would be a four year course with a preponderance of science and would lead to a degree of Bachelor of Science in Engineering. Specialization would be left for graduate studies.

Thus a committee of representative engineers of long experience in industry has indicated that there is a need for engineers trained in fundamental science, and that these engineers can be released for such fundamental work by providing Technical Institute graduates to do sub-professional work.

It is often said that fundamental courses are all right for large companies that have training programs, but that small companies require engineers trained in specialties so that they can start work at once. One of the members of this committee is a mechanical engineer who owns a small company manufacturing mechanical equipment. He believes that a broad fundamental training is very important in a small company where the engineers have to be versatile because the company cannot afford an engineer for each specialty.

Allis-Chalmers has had a training program for many years for graduate engineers. This training costs the company about $10,000 per year per man. It consists of lectures and on the job training in various departments. The same training is given to all engineers regardless of specialty. In the recruiting of engineering graduates no specialized training is required of these graduates. A sound background of good scholarship in fundamental subjects is one of the principal standards for picking the man.

In addition to the practical training given in the Allis-Chalmer's plants, courses also are given in graduate engineering subjects by members of the faculty of the Illinois Institute of Technology. These courses may be used for a Master's Degree. The instructors come to the plant to give the courses in the evening. The Company pays a third of the engineers' tuition upon registration for a course and another third upon satisfactory completion of the course. A number of men obtain advanced degrees in engineering each year in this way or through the University of Wisconsin's graduate courses given in Milwaukee. Research work for the thesis may be some problem that is being worked on for the company on company time or it may be a problem of no direct interest to the company. In the latter case the work is usually done on the student's time, but with company equipment in the plant.

Value of Fundamental Scientific Training in Industry

Engineers usually enter one of four major fields in industry:

1. Design.
2. Production.
3. Sales.
4. Research and Development.

Scientific training is valuable for design because it provides the basis for the creative work necessary. It gives the design engineer the background that enables him to design machines and processes that will work commercially, and that will not violate some fundamental laws. Design is similar to research in that it requires imagination and an ability to visualize new equipment and processes and also new uses for old equipment. A sound background of science is necessary to enable the design engineer to read its literature and hence utilize all new discoveries to produce modern equipment.

Engineers employed in production in today's intricate manufacturing must be well schooled in science because production is no longer an application of brute strength to the fabrication or processing of materials; it is no longer a "cut and try" procedure; nor is it a sterile following of conventional patterns which have proved successful in the past. But rather it is an application of scientific principles to operations to give maximum efficiencies. Often production engineers are able to make improvements in processing that eliminate much expensive labor. Since modern production equipment is highly scientific, an engineer who operates and maintains this equipment also must know his science. Quality control by statistical analysis is an example of the use of science in manufacturing. Machining also has been improved as the result of scientific studies on metal removal.

Sales engineering is a field with increasing interest to engineers. Although this field is often entered by many without engineering training, nevertheless sales engineering is a real profession and requires scientific knowledge. The products of highly scientific design and manufacture can be sold only if they fit into the customer's plants and processes. A wide variety of conditions and needs are encountered by the sales engineer. He must be able to discuss each customer's technical problems with engineers in that business. It would be impossible to train engineers in such a wide variety of technologies, but a basic training in science allows the sales engineer to quickly understand and adapt himself to any of the special conditions he meets.

In research and development, it is usually conceded that a thorough knowledge of science is essential. Here on the frontiers of knowledge, only the guideposts of the fundamental sciences can be used as the take off for expeditions into the unknown. There is no dividing line between the scientist and engineer in research and development. The data obtained in this field are necessary for use by the design engineer to enable him to design large scale equipment and processes. The future of all manufacturing and engineering is determined by research. Only by having a thorough knowledge of science can an engineer progress in research, and to get this knowledge graduate training is desirable.

About half the engineering students do not practice engineering as a life work. They may go into patent law, purchasing, construction, or any business function. Can these engineers profit by scientific training? I think they can. Science is simply common sense or logic applied to natural phenomena. The scientist gets the facts and weighs the importance of each before coming to a decision. This is good training for almost any life career. It is much better than specialized engineering training for which these engineers will never have any use.

Industrial Needs for Scientifically Trained Engineers

Industry requires engineers who have had four years of study in the fundamental sciences such as physics, chemistry, mathematics, thermodynamics, electricity and mechanics. Such graduates in non-specialized engineering should then

enter industries' training programs or should take graduate work in the universities for advanced degrees.

These engineers should be used for professional duties in industry with Technical Institute graduates and other technician's help to assure maximum utilization of limited numbers of basically trained engineers. Such education and utilization of engineers will raise the standards of engineers and assure industry of an ample supply of adequately trained men.

There is not complete agreement in academic circles on the advisability of fundamental training of engineers and their graduation without designation. Therefore, it is suggested that a course in "Fundamental Engineering" be established in engineering schools as an alternate course with present specialized courses. It is believed that with competent and enthusiastic faculties for this course its graduates will be so successful that eventually industry will demand engineers with this fundamental training.

College Notes

Charles Pratt, President of **Pratt Institute**, has announced his intention of retiring. He will, however, continue to serve until his successor is appointed. The Board of Trustees has signified its intention of electing him its chairman at that time, thus preserving the continuity of his service. Mr. Pratt, who is a grandson and namesake of the Founder of Pratt Institute, took over its chief administrative post from his father, the late Frederic B. Pratt, in 1937, and has been its executive officer during its transition from a technical institute to a degree-granting institution.

After eight months as Acting President of **Fenn College**, G. Brooks Earnest has been elected to the presidency of the Cleveland college.

A new Acoustics Laboratory where sound that man cannot hear, as well as audible noise, will be investigated has been established in the Engineering Center at **Columbia University.** When completed, the Laboratory will provide facilities for research and instruction in electroacoustics, architectural acoustics, ultrasonics, psycho-acoustics, speech, noise control, and musical acoustics.

Dexter S. Kimball

Dexter S. Kimball, former Dean of Engineering at Cornell University and a Past President of the American Society for Engineering Education, passed away on November 1, 1952. For more than half a century, Dean Kimball was one of the best known and best loved personalities on the Cornell faculty. He was nationally prominent in the field of engineering.

Dean Kimball was born in New River, New Brunswick, Canada on October 21, 1865. He received the A.B. degree in engineering from Stanford University in 1896 and the degree of mechanical engineer from Stanford in 1913. He held honorary degrees from the University of Rochester, Case School of Applied Science, Kansas State College, Northeastern University and Lehigh University.

He was honored by several scientific societies and received the Lamme Award from the ASEE in 1933.

The Modern Engineer Should be Educated as a Scientist. II. In College

By GORDON S. BROWN

Professor of Electrical Engineering, Massachusetts Institute of Technology

It is probable that you would take many young engineers by surprise if you told them that they should be educated as scientists. They would point out that engineers are men of decision, of accomplishment, that they get things done in the framework of the hard cold world. The significance of an education in science becomes clearer, however, if they appreciate first, that professional engineering is the application of the practical accomplishments of the scientist to the service of mankind, and second that engineering as practiced in the mid-twentieth century has a much more scientific flavor than it had only a few decades ago, and third that many scientists have demonstrated talents that present day engineers would do well to emulate. The words "as a scientist" then acquire a subtle meaning, but they should not be interpreted too narrowly for this discussion. It is more to the point to say that engineers should be educated "with depth in the sciences" rather than say "as a scientist."

If we take a look back and review the growth of technology as Professor Goodlet * has done in a paper he read before the Institute of Electrical Engineers of South Africa, we may note several significant facts. For example, throughout the period of the first industrial revolution, technology was such that many engineers succeeded in accomplishing great engineering feats—the building of bridges, the design and manufacture of heat engines, the weaving of cloth, the multitudinous systems of transportation, and even the wireless, in the face of an inadequate and often erroneous statement of basic theory. Many of the great inventions of our times came into being without the benefit of science, and often in spite of the predictions of eminent scientists.

But engineering and science are both relatively young and growing fields. It is only a mere two hundred years or so since systematic scientific research began to get a hold in the great universities of the world. While science was young and growing, common sense and intuition still found great scope for application in engineering. Up to about the turn of the century engineers were able to pioneer in many new fields even though they did not know all the fine points as to the why. Their problems were such that to know the how was sufficient, for their tasks were largely to perform orderly arrangements of the known experiences of their day. During this period much of the study by the physical scientists was concerned with the establishment of truth within the technical world then created by engineers. Then, as a consequence of these truths of the scientist there gradually spread throughout the various fields of engineering a demand for a quantitative exactness of statement about more and more things. Engineers soon learned the value of quantitative design as a substitute for empericism. The establishment, early in the 19th century, of professorships in engineering in universities and of the technical institutes that have since attained full in-

* Goodlet, B. L., "The Universities and the Engineering World." *Trans. S. A. Inst. Elect. Eng.*, Aug. (1950), 231.

ternational professional stature resulted largely from this demand for quantitative exactness.

Engineering is Complex

But the situation today is in marked contrast with what it used to be. The complexities of engineering technology and the demands for creative engineering are far greater than those of even a decade ago. A sharpening up of old emperical tools is no longer sufficient. Engineering has become vitally dependent on science, and abstract scientific analysis often calls the shots for engineering. As a result of the accumulated know-how of several generations of concentrated engineering aided by pure and applied scientific effort, we now have a vast store of fundamental knowledge. Thus, technical education as we think of it today has a digestion problem. Obviously, the solution is not merely to demand more of a student's time for professional study. In fact, modern demands for the education of the "whole engineer" resulting from the vast social influence he now wields, have encroached on the time formerly available for professional activities. What then has happened, what must happen in the years ahead?

Fortunately, we are aided in small degree by the feedback process inherent in our social system. The day-by-day activity of our youth is conducted in an environment that is heavily technical —in the home, in school, and even at play. The effect is to augment a young engineer's motivation for technical study. Then to, as the tempo of life has quickened, the high schools and preparatory schools have increased their skill at preparing boys for assimilating concentrated courses in mathematics, physics, chemistry, engineering, and humanities. But we cannot expect too much here and assume that high schools exist merely to prepare boys for college; their job is also to train youngsters for life. Neither can we assume that we have an inexhaustible pool from which to draw, for as Dean Hollister mentioned in his inspiring presidential address at the Annual Meeting at Dartmouth this summer we cannot expect any great increase in the percentage of high-IQ youngsters that will enter engineering. This situation is serious in the face of an increasing demand for engineers. Hence, we must make the most of those whom we get and upgrade them, technically and in creative capacity, above the level we have heretofore believed adequate.

Creative Synthesis

In making the most of what we can get we must not be deluded into thinking that our job is merely to turn out knowledgeable young men, walking encyclopedias, full of facts. On the contrary, we should aim to produce a person trained in basic principles and skilled at applying what we mean by creative synthesis in new complex engineering situation. The need is for composers in contrast with mere arrangers. To this end, the sifting of curricula content in colleges and universities must continue. Our faculties must comprise more outstanding men. Our skill at discriminating between fundamental fact and mere useful knowledge in terms of today's technology must continue upward. Above all, more and more of us must realize that the engineer of tomorrow cannot be a person who merely makes decisions and gets answers to today's problems. He must not be merely a high-powered technician. On the contrary, he must be that kind of professional individual whose knowledge of the modern fundamental discoveries of science is first rate; he must be able to sense those discoveries from which will spring the great new engineering developments of tomorrow; he must have experienced the thrill of creative accomplishment in an environment where the fundamentals of science are practiced. He must not have been reared on mere drill at problem solving. The decisions and answers he must make are those that pertain to the new and unplowed areas of applied technology if he is to attain the stature of a creative engineering leader of the mid-twentieth century. The forward looking engineers and educators of today clearly realize—

as Professor Goodlet says—that "science until recently the servant of engineering, is becoming its master and that advances in engineering are now often made not by engineers but by scientists."

As an illustration of the close coupling of science and engineering let us take a look at any of the present-day growing fields of science or those that have recently reached the domain of engineering. In the early phases, the topic was full of problems that were of a challenging abstract kind and attracted the attention of scientists who found opportunity for abstract theoretical thinking. Their efforts pointed up many problems that required scientific study and culminated in throwing up an umbrella of sound scientific thought. Working in concert with them were the people whom I call engineers. They knew their fundamentals, they were bold and creative and they had an urge to apply their efforts to today's needs. They in turn sifted, codified, and tabulated the scientific theories so that the issues eventually became clearer, the useful distinguishable from the interesting, and they applied the results to the benefit of society and industry. Finally great waves of people who are often called engineers, but who are perhaps better thought of as practitioners or technicians, were swept under this umbrella and produced, sold, and serviced the efforts of the engineers in the daily market. The engineers of whom I speak here will certainly not bother to argue the words—"trained as Scientists" or "trained in science."

Illustration

Another illustration of this close coupling is the importance that industry attaches to science and research and its dependence on them for sustained success. All organizations in the great industries of today, such as mechanical, electrical, chemical, aeronautical, maintain their own research organization or have their engineers keep abreast of the professional literature wherein the results of research in pure and applied science are reported. In modern times the new developments in industry result from the synthesis by engineers of new discoveries in pure and applied science. The interval from the time of discovery of new scientific phenomena and theories to their industrial exploitation is today only a matter of a few years at most. Because of this tempo, we have been forced into an operating system in which large groups of nonconformist engineer-scientist teams operate with a very clear plan of coordinated effort. You will agree, I hope, that any engineer who does not know his science would be a technically illiterate member of any such team.

But not every engineer trained as a scientist will practice engineering in the company of scientists or in a creative environment, or spend any of his own time in abstract thought. Many will be concerned wholly with bread and butter, or cookbook engineering rather than with the advancement of technology. A sound education in the sciences is an unnecessary if not an undigestible luxury for a cookbook engineer, but I would hope that engineering schools of the future will reduce to a minimum the number of cookbookers among their all to few students. Spoon-feeding with facts is not the whole aim of modern engineering education. Admittedly we must do some of it as part of an undergraduate program, in getting started so to speak, and certainly many students whom we admit will fail to measure up to our ideals yet still will serve humanity well. Our goal, however, must be to choose our raw material wisely, to salvage as many as possible from those who stumble along the way, and to offer graduate opportunities for as many as have the appropriate intellectual capacity.

Aims in Educating Engineers

An analysis of these situations leads to the conclusion that the education of the leading engineers for a creative professional career should have the same or nearly the same characteristics or qualities as the education of the scientist—with, however, the stipulation that it make them good engineers and not medi-

ocre scientists. That is to say, these engineers must, in addition to knowing science, know the practical world. Their concern is basically one of practical utility, but of tomorrow's vintage, not yesterday's. Their job is to satisfy the material needs and desires of people within their willingness or capacity to pay. They must be leaders of men. They must consider manufacturing problems, labor conditions, and above all have sound judgment. They cannot be mere tradesmen or technicians, since they must make use of the accumulated knowledge and techniques of the mathematician and the scientist, as well as use all the tricks of their own trade. While being primarily interested in knowledge because it is useful, in contrast to the scientist who is interested in knowledge to uncover the truth about the real world, they do not restrict all their interest to knowledge that is useful today. Their sights are upward—they clearly have their eyes set on tomorrow.

So much for the aims. As educators how well do we live up to them? Two general matters will bear discussion, namely, (1) as science advances and as engineering becomes more scientific do we keep up-to-date in the matter of curriculum substance, and (2) do we create as often as we should the best environment for teaching engineering?

On the question of curriculum take for example the situation that exists now in college physics. The last decade has witnessed a tremendous growth in so-called modern physics with the birth of atomic physics and physics of the solid state, just to cite two new fields. A knowledge of both is important to modern engineers. But the curriculum hours for teaching physics are limited. Hence it is essential that we review the distribution of academic effort within the science and engineering departments as a continuing activity and be constantly alert to opportunities which would result in the engineering departments teaching much of the classical physics as an integrated part of engineering, while the physics departments use their allotment of time to teach modern physics to engineers. Because of the heavy expenditures of time and money associated with any program of modernizing laboratory courses, I suspect that many of us have failed to incorporate in engineering laboratory courses much subject matter that is now taught in freshman and sophomore physics laboratory just because it always has been, when actually it could greatly strengthen the engineering subject.

Similar remarks can be made about the teaching of mathematics. As engineering has continued to upgrade, the substance of mathematics has become more and more an integral part. Not many years ago function theory, operational methods, Fourier transforms, and Fourier series were taught exclusively by the mathematic departments. They were rarely used or even mentioned by engineers, except perhaps in graduate work. Now they have become indispensible tools in engineering subjects such as circuit theory, applied mechanics, and so forth. Mathematics courses for engineers have thus been freed to treat more advanced topics and give more training in abstract thought.

Improvement in Teaching

In spite of all the ASEE meetings that discuss the teaching of engineering we still observe need for improvement. The substance may be all right but the subject often does not take. Is it because we fail to give the student those concepts that will allow him to be creative and fail to show him how to use them? Do we stop short in presenting fundamentals in order to reach the handbook stage of so-called engineering design? Do we teach rather than educate? Speaking strictly as an electrical engineer, it seems to me that many students graduate with a wholly inadequate understanding of modern field theory. To many it appears as a useless scientific abstraction. While most students can handle a statics problem such as plotting a field distribution or designing a simple electromagnet, too many are stopped dead in their tracks when the problem is made dynamic by introducing

time as a variable with attendant space propagation. The general rule seems to be that only students in the communications option are expected to take field theory seriously, and these limit their interest wholly to radio. Perhaps the advent of the transistor, and the wide engineering interest in physics of the solid state will improve this situation. As another example, witness the recent state of the teaching of electrical machinery. Many subjects are limited to the treatment of the machine in the static state. There is great preoccupation with steady-state performance. There is rarely much substance that allows a student to be creative about unusual combinations of fields and conductors, especially those that might exploit non-linearities. More recently an emphasis on the machine as an energy conversion element † in a system has emerged. Also the subject of feedback control has aroused a greater interest in the dynamics of machine behavior with the machine here relegated to the status of a circuit element in a complicated energy conversion system. While some detailed understanding of the design technique of specific elements of a routine nature may have been lost in this evolutionary process, it seems to me that the student may be better educated since his emphasis on the system problem and his guidance in abstract thinking have been increased.

Need to Develop Wisdom

Fortunately, however, communication within academic and engineering circles is sufficiently effectual that in so far as curriculum substance is concerned there is little point to an extensive discussion. Our concern is not primarily with how well we present our facts and figures or how well we build up the student's knowledge. Rather, it is with, how well we succeed in training him to use his mind, or with how well we inculcate in him the so-called scientific method and give him the collatoral capacity to think creatively in the abstract about basic fundamentals as he works with his facts and formulae. In other words, our concern is whether we achieve any development of wisdom in addition to imparting knowledge. And the two are vastly different as so beautifully described by Cowper:

"Knowledge and wisdom, far from being one,
Have ofttimes no connexion. Knowledge dwells
In heads replete with thoughts of other men,
Wisdom in mind attentive to their own.
Knowledge, a rude unprofitable mass,
The mere materials with which wisdom builds,
Till smoothed and squared and fitted to its place
Does but encumber whom it seems to enrich.
Knowledge is proud that he has learned so much;
Wisdom is humble that he knows no more." ‡

While we must not deprecate the importance of factual information to an engineer, the item of greatest importance to this discussion is that whereas it has long been accepted that embryo scientists shall have training in research while in college, the training of embryo engineers in research, or perhaps development, on an organized basis is a relatively recent innovation. In fact, at the level that I believe it should be practiced, I doubt if it is at all widespread. In many institutions there is no thesis requirement for a B.S. degree in engineering while in others, thesis is not even required for an M.S. degree. In too many instances, the student attends lectures, performs canned experiments, and solves problems closely related to the specific course for his entire four years. At no time does he have the need, let alone the urge, to synthesize from several different fundamental concepts, to create as an engineer. His efforts are wholly those of analysis limited to fragments of a problem.

But powerful forces are at work within engineering and science that offer many

† A. E. Fitzgerald and Charles Kingsley, Jr., "Electrical Machinery." An integrated treatment of AC and DC machines. McGraw-Hill Book Co., Inc. 1952.

‡ William Cowper, "The Task," Bk. VI, lines 88–98, 1785.

precious opportunities for helping both teacher and student. Not only has the sustained cold war promoted an extensive amount of government sponsored research in educational institutions, but many industries have realized that they must sponsor research in educational institutions for their own protection. I hope the public utility and power industries come to this realization before vitality and creative thinking in their field disappears completely from engineering schools.

Major Change in Thinking

Perhaps without fully realizing it we are on the threshold of witnessing a major change in our thinking. The recent summer meeting of the ASEE held an interesting panel discussion on, "Training in Research." Speakers discussed "thesis and seminar," "sponsored research," "training in research," and related topics such as "pure versus applied," "the right atmosphere," and so forth. The speakers all talked freely about the wonders of the scientific method and of the integrating value of research in so far as it tied together the various fundamentals of a curriculum; of the experience it gave in organizing an attack on a problem as the researcher filtered, decoded, rejected, interpreted, synthesized, and decided; of the effectiveness with which research brought opportunities for new abstract thinking into the environment of the engineer. The speakers were faculty members of American engineering colleges. Some were engineers, others were scientists. What they all were saying was that participation in a live enterprise in a creative scientific environment, with fertile opportunity for abstract thinking where men were not afraid to do new things and tread unworn paths, was good education. It seems to me that they were affirming the objective of this panel discussion under a different title.

Research or development projects in both engineering and science performed on campus under the supervision of a faculty member are priceless adjuncts to an institution's program. It is important that we insist, however, that the projects be such that a student can work as an assistant to a faculty member, or be a member of the engineering team and have the thrill of being part of a creative environment. In many instances he can handle a segment of the problem on his own as a thesis. In either case, he is withdrawn for awhile from the treadmill of taking courses and given a chance to stand on his own feet. If properly guided he can be given the collatoral experience of seeing the whole problem, seeing how subtly and surely its solution cuts across many fields of specialization and thereby see, perhaps for the first time, the interrelationships of substance within his curriculum. He can note how the problem is often first scanned in terms of such simple concepts as energy balance—kinetic, potential, thermal, chemical, electromagnetic, and so forth—that it involves measurement if it is to be specific, and energy conversion if it performs useful work in the real world, that the whole problem can be first examined in a pseudo abstract sense, that the tools of the mathematician permit effective abstract thought, that there often exist analogies of the whole situation in other fields. In several instances, he will see that the tempo of technology is so great that the engineer cannot wait for the scientist to get the answers to basic questions, so he must pinch hit himself as a scientist. When such conditions exist within faculties of engineering schools, the student both undergraduate and graduate, has an excellent experience if he can be cut in on the enterprise. Finally, if the problem is creative in an engineering sense, the student will see that it takes years to reach an objective, that he must be alert to the temptation to substitute lower standards of accomplishment for persistence and patience, and that in the appraisal of the multitudinous questions for which no quantiative data exist there appears the opportunity for the application of that something called *sound engineering judgment,* a vital characteristic of all good engineering.

Sponsored Research

Perhaps not all institutions are willing to have the kind of engineering enterprise on their campus that will provide such an environment. I hold the opinion that modern engineering education needs this kind of *environment* for the learning of today's substance and that society should see to it that all the schools which can, do. I do not think that so-called cooperative courses, where the student is a term at school and a term at the works, wholly meet the needs of the times though they are important in themselves. While they offer an opportunity for participation in an engineering environment, only rarely is it as broadly creative as a college campus can offer. The questions that should be asked when making a choice of project are not whether it is basic or fundamental, applied research or development, but whether:

A. The institution has in existence or potentially available the facilities and staff needed for the work?
B. The faculty has a strong interest in this kind of work, and whether it would both broaden and deepen their scholarship?
C. The program falls within the areas of activity covered by the educational program?
D. The activity will offer the opportunity for student participation?

The question of research or development work under government or industrial sponsorship is one that institutions and industry should face squarely.§ While some commercial organizations may be hostile toward university participation in their fields, it cannot be denied that challenging development work on a paid job under a professor's direction is an extremely valuable educational experience for the graduate. It can considerably enhance his usefulness as a member of an industrial organization. The general idea here expressed has for decades been in widespread use in the medical profession in the program of internship undertaken by young doctors of medicine before entering private practice. Furthermore, the vitality and professional flavor of the academic engineering environment can be advantageously nourished by close and flourishing industrial association. The flight of dynamic professors from the university to industry can often be retarded by establishing on-campus engineering research. Clearly, an institution should demand the opportunity to cultivate such association without surrendering academic freedoms and the right to publish. It should insist on a tempo of activity that will permit of student participation at a pace commensurate with an academic program, and should assure itself that the effort will contribute to the academic strength of the institution rather than merely solve an industrial problem. If it holds to these requirements it will not be trespassing on the prerogatives of commercial research organizations. Obviously, no stigma should attach to an academic thesis performed on a paid job. I firmly believe in development engineering enterprises within college departments, such as servomechanisms laboratories wherein genuine engineering responsibility is accepted, just to cite one I know well, if modern engineering graduates are to be trained to the level of professional competence that the times necessitate. I do not believe we go far enough when we assign to engineers only small fragmentary so-called basic problems. They may be all right if we are only searching for truth, but they are rarely comprehensive enough to exploit fully the capacity of the engineer for creative synthesis.

Case Method

Closely allied to the general problem of research is the technique of engineering instruction by the project or case method. Specific cases do not need to be new original problems in order to be a substitute for research when considered in relation to the student's state of knowledge.

§ Sherwood, T. K., *Chem. and Eng. News*, Am. Chem. Soc. 2 (1950), v. 28, p. 456.

This is particularly true of undergraduates. Often the best examples emerge from faculty participation in research. Professor E. P. Neumann of the Mechanical Engineering Department at MIT demonstrated this a year or so ago. A group of his undergraduate students studying thermodynamics were assigned the problem of maintaining the cockpit temperature in a supersonic aircraft at a level that would be acceptable to the pilot. The group was told to absent themselves from the regular classroom session in thermodynamics while they handled this problem. Their accomplishments were startling to say the least. Not only did they learn to apply the principles of thermodynamics, but they uncovered and applied principles usually learned in other fields but which were here part of the problem. They had to learn about supersonic air flow, especially as related to thermodynamics. They found it necesary to discuss the problem with people of various professional backgrounds. At the end of the term they took the regularly scheduled final examination and did essentially as well as the better students who studied the regular subject. Instead of submitting to the usual experience of covering so many thermodynamic principles, they actually uncovered a few on their own. While the topic was one in which academic achievement could be quantitatively assessed by the instructor, it brought into focus in a very real way several associated disciplines of engineering, for it necessitated that the student obtain quantitative answers to real problems on a time schedule and subject to the limitations of engineering feasibility, economics, good common sense, and so forth.

On another occasion a group of electrical seniors were assigned the task of designing and promoting commercially a gas-discharge flash light for amateur photographers. Still another group of mechanicals tackled an improved design of commercial vacuum cleaner. Each project cut across many fields of specialization and introduced both technical and non-technical problems of a creative kind.

Summary

In conclusion, let me summarize my contentions as follows. Modern professional engineering is the application of natural laws and phenomena to the service of man. It leans heavily on the modern discoveries of physics, mathematics and chemistry. The future promises such heavy demands on engineers that the best of those whom we train must be developed to the highest state of professional skill commensurate with their latent talents and the capacity of educators to develop them. This calls for extensive training of engineers in depth in the associated fields of science in a creative environment under the guidance of a faculty which itself is creative. In addition to the inclusion of strong basic science courses, the curriculum should offer substantial scope for student participation in research or make frequent use of the case method of instruction with creative examples as a means of illustrating the application of modern science to engineering work.

Section Meetings

Section	*Location of Meeting*	*Dates*	*Chairman of Section*
Allegheny	West Virginia University	April 17–18, 1953	C. H. Cather, West Virginia University
Illinois-Indiana	Rose Polytechnic Institute	May, 16, 1953	H. A. Moench, Rose Polytechnic Institute
Kansas-Nebraska	University of Kansas	Oct. 24–25, 1952	M. A. Durland, Kansas State College
Michigan	Detroit Institute of Technology	May 9, 1953	C. C. Winn, Detroit Institute of Technology
Middle Atlantic	Manhattan College	December 6, 1952	W. B. Plank, Lafayette College
Missouri	Washington University	April 11, 1953	G. F. Branigan, University of Arkansas
National Capital Area	Catholic University of America	Oct. 7, 1952	L. K. Downing, Howard University
	Howard University	May 9, 1953	
	University of Maryland	Feb. 3, 1953	
New England	Worcester Polytechnic Institute	Oct. 18, 1952	E. T. Donovan, University of New Hampshire
North Midwest	Marquette University	Oct. 9–10, 1953	S. J. Chamberlin, Iowa State College
Ohio	University of Cincinnati	May 2, 1953	H. K. Justice, University of Cincinnati
Pacific Northwest	Washington State College	April 24–25, 1953	J. P. Spielman, Washington State College
Pacific Southwest	California State Polytechnic College	Dec. 29–30, 1952	C. E. Cherry, College of Marin
*Rocky Mountain	University of Wyoming		C. A. Hutchinson, University of Colorado
*Southeastern	Louisiana State University	March, 1953	D. V. Terrell, University of Kentucky
Southwestern	University of New Mexico	April 3 & 4, 1953	M. L. Ray, University of Houston
Upper New York	Alfred University	October 10–11, 1952	R. M. Campbell, Alfred University

Members of the Society are welcome at all Section Meetings

*** No Date Set.**

New Members

ABRAMSON, HYMAN N., Act. Associate Professor of Aeronautical Engineering, Texas A. & M. College, College Station, Texas. H. W. Barlow, E. E. Brush.

ALLING, EDWIN S., Assistant Professor of Civil Engineering, University of New Hampshire, Durham, N. H. E. T. Donovan, R. R. Skelton.

ALMFELDT, MAURICE W., Associate Professor of Engineering Drawing, Iowa State College, Ames, Iowa. J. S. Rising, C. G. Sanders.

ATHERTON, RICHARD, Assistant Professor of Mechanical Engineering, University of Massachusetts, Amherst, Mass. J. B. Longstaff, J. H. Dittfach.

BASSOE, BJARNE, Secretary General, The Norwegian Engineering Society, Oslo, Norway. C. E. Davies, A. B. Bronwell.

BERNARDI, SALVATORE D., Assistant Professor of Mathematics, New York University, New York, N. Y. H. A. Giddings, I. A. Carl.

BIEDENBACH, JOSEPH M., Instructor in Science Department, General Motors Institute, Flint, Mich. G. L. LaPrade, J. B. Keehner.

BIGELOW, CLIFFORD G., Assistant in Industrial Engineering, Columbia University, New York, N. Y. F. C. Winter, S. J. Montgomery.

BURNHAM, GEORGE H., Associate Professor of Physics, Norwich University, Northfield, Vt. S. Rubinsky, S. N. McIntire.

CARLSON, EHRET C., Instructor in Advanced Engineering Education, International Business Machines Corporation, Fishkill, N. Y. R. W. Wolslegel, E. E. Moyer.

CHINN, JAMES, Assistant Professor of Civil Engineering, University of Texas, Austin, Texas. P. M. Ferguson, W. L. Moore.

COLLINS, STEWART B., Assistant Professor of Industrial Coordination, Drexel Institute of Technology, Philadelphia, Pa. H. R. Bintzer, C. A. Kapp.

DAVIS, EARLE R., Professor and Head, English Department, Kansas State College, Manhattan, Kans. M. A. Durland, L. Helander.

EGNER, CARL A., Associate Professor of Civil Engineering, Purdue University, Lafayette, Ind. F. W. Stubbs, Jr., R. B. Wiley.

EL-MELEHY, M. A., Assistant Professor of Electrical Engineering, University of Arkansas, Fayetteville, Ark. G. F. Branigan, N. H. Barnette.

FEDORCHUCK, HENRY N., Assistant in Mechanical Engineering, University of Detroit, Detroit, Mich. H. Gudebski, W. P. Godfrey.

FOSTER, ARTHUR R., Assistant Professor of Mechanical Engineering, Northeastern University, Boston, Mass. A. J. Ferretti, H. K. Brown.

GENSAMER, MAXWELL, Professor of Metallurgy, Columbia University, New York 27, N. Y. J. M. Garrelts, P. B. Bucky.

GERSHON, JOSEPH J., Director of Engineering, DeForest's Training, Inc., Chicago, Ill. A. B. Bronwell, O. I. Thompson.

GMEINER, PAUL, Instructor in Advanced Engineering Education, International Business Machines Corporation, Poughkeepsie, N. Y. R. W. Wolslegel, E. E. Moyer.

GODDARD, WILLIAM E., Vice President and General Manager, Canadian Institute of Science & Technology, Ltd., Toronto, Ontario, Can. E. A. Allcut, W. P. Ferguson.

HULTQUIST, PAUL F., Instructor in Applied Mathematics, University of Colorado, Boulder, Colo. C. L. Eckel, C. A. Hutchinson.

JOHNSON, RAY C., Instructor in Mechanical Engineering, University of Rochester, Rochester, N. Y. R. R. Kraybill, R. F. Eisenberg.

KLUGE, RALPH W., Professor of Civil Engineering, University of Florida, Gainesville, Fla. J. E. Kiker, Jr., T. L. Bransford.

LADD, ROGER E., Massachusetts Institute of Technology, Cambridge, Mass. T. F. Jones, Jr., D. C. Ladd.

LANG, WILLIAM A., Manager, Educational Assistance Dept., Minneapolis-Honeywell Regulator Co., Philadelphia, Pa. W. J. Stevens, K. W. Riddle.

LANHAM, FRANK B., Assistant Secretary, American Society of Agricultural Engineers, Saint Joseph, Mich. H. J. Barre, R. Olney.

LANZ, LOUIS T., Coordinator, Technical Personnel Procurement Dept., Monsanto Chemical Company, St. Louis, Mo. R. F. McCook, J. J. Healy, Jr.

LEWELLEN, JAMES G., Assistant in Aeronautical Engineering, Parks College of Aero. Tech., East St. Louis, Ill. N. C. Beck, H. R. Grummann.

LEWIS, LAVERNE F., Associate Professor of Physics, U.S.A.F. Institute of Technology, Dayton, Ohio. J. H. Belknap, H. F. Marco.

LINTON, FRANKLIN H., Director of Placement, Wentworth Institute, Boston, Mass. W. C. White, M. N. Arlin.

LISK, HAROLD H., Director, Publications Dept., Norden Laboratories Corp., White Plains, N. Y. W. R. Woolrich, A. B. Bronwell.

LOTTICH, PHILIP B., Director of Admissions and Coordinator of the Cooperative Program, Illinois Institute of Tech., Chicago, Ill. J. G. Duba, R. G. Owens.

LUNDERGAN, CHARLES D., Acting Head, Dept. of Aeronautical Engineering, Parks College of Aero. Tech., East St. Louis, Ill. N. C. Beck, H. S. Wood.

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199 new members elected this year

* * *

Pacific Southwest Meets at San Luis Obispo

The Pacific Southwest Section of the Society plans its 1952 annual meeting for Monday and Tuesday, December 29 and 30 at the California State Polytechnic College at San Luis Obispo, California. Members residing in the States of California, Arizona, Nevada and New Mexico and the Territory of Hawaii are assigned to this section. A program is being arranged under the chairmanship of C. M. Duke of the University of California, Los Angeles, in keeping with the society's theme the "Year of Evaluation." About twenty offers of papers have been received to date. Harold Holmes of California State Polytechnic College is Arrangements Chairman, Carlton E. Cherry, C. M. Duke, and Joseph B. Franzini are Chairman, Vice Chairman and Secretary of the section respectively.

* * *

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Reprints of the **Report of the Committee on Improvement of Teaching** which appeared in the September, 1952 Journal of Engineering Education. Checks and orders should be sent to the Journal of Engineering Education, Northwestern University, Evanston, Illinois. The price is $8.00 per hundred and 15¢ per copy in quantities under 100.

Young Faculty Members . . . . .

PAPER COMPETITION

ELIGIBILITY: Members of ASEE not over 36 years of age in June, 1953.

AWARDS: First prize $200—Second prize $100.
Awards will be presented to recipients at the Banquet at the Annual Meeting of ASEE, University of Florida, June 25, 1953.

SUBJECT: Papers should deal with some constructive phase of improvement of engineering education. Participants are encouraged to select their own subject matter and titles within the broad framework of improvement of engineering education. In general, the papers should not be of a technical nature. The following are suggestions of the type of subject matter to consider:

a. How can the student learn to deal with new and unfamiliar situations with originality and well-ordered professional thinking?

b. What are the most important qualifications of undergraduate teachers of engineering?

JUDGING: Each Section will appoint its own judging committee and select one winning paper. The winning papers from the Sections will be reviewed by a national judging committee for the final awards.

SUBMISSION OF ENTRIES: Papers can be submitted to the folowing persons in the ASEE Section in which the participant resides:

Section	*Final Date*	*Submit Entry To:*
Allegheny	April 1, 1953	L. Zee, West Virginia University, Morgantown, W. Va.
Missouri	April 1, 1953	F. H. Conrad, School of Mines, Rolla, Mo.
National Capital	March 3, 1953	L. K. Downing, Howard University, Washington, D. C.
North-Midwest	April 1, 1953	S. J. Chamberlain, Iowa State College, Ames, Iowa
Ohio	March 14, 1953	H. K. Justice, University of Cincinnati, Cincinnati, Ohio
Pacific-Northwest	March 15, 1953	J. P. Spielman, State College of Washington, Pullman, Wash.
Rocky Mountain	March 10, 1953	R. E. Leffel, University of Colorado, Boulder, Colo.
Southeastern	Feb. 27, 1953	M. Baker, University of Kentucky, Lexington, Ky.
Southwestern	April 2, 1953	R. D. Slonneger, University of Houston, Houston, Tex.
Upper New York	March 15, 1953	A. D. Taylor, 18 Campus Drive East, Snyder 21, N. Y.

The following Sections have not indicated a final date for entries, but papers submitted prior to March 15 will be considered:

Illinois-Indiana	—	H. A. Moench, Rose Polytechnic Institute, Terre Haute, Ind.
Kansas-Nebraska	—	M. A. Durland, Kansas State College, Manhattan, Kans.
Michigan	—	C. C. Winn, Detroit Inst. of Technology, Detroit, Mich.
Middle Atlantic	—	W. B. Plank, Lafayette College, Easton, Pa.
New England	—	E. T. Donovan University of New Hampshire, Durham, N. H.
Pacific-Southwest	—	C. E. Cherry, College of Marin, Kentfield, Calif.

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Midwinter Meeting
of the
Engineering Drawing Division of the A.S.E.E.
University of Nebraska, Lincoln, Nebraska
January 29, 30, and 31, 1953

The Drawing Division was invited to hold its Midwinter Meeting at the University of Nebraska during the annual meeting at East Lansing, Michigan. The Executive Committee accepted this offer and fixed the dates of January 29, 30, and 31, 1953. The program includes:

Thursday, January 29:

9:00–10:30 a.m.	Registration, 2nd Floor, Bancroft Building
10:30 a.m.	Meeting, Auditorium, Bancroft Building
	Greeting: Dean Roy M. Green, College of Engineering and Architecture, University of Nebraska
	Response: (For the Division) Dean Jasper Gerardi, Chairman of the Division
	"Reduction of Forces in Space by Graphical Methods," Professor E. J. Marmo, Department of Engineering Mechanics, University of Nebraska
12:00 noon	Luncheon, Student Union
1:00– 1:15 p.m.	Board Buses for Boys' Town (Arrive at Boys' Town about 2:40)
2:50– 4:30 p.m.	Inspection of Boys' Town
4:30 p.m.	Board Buses for Lincoln (Arrive at Lincoln about 6:00)
7:00 p.m.	Executive Committee Meeting
8:00–10:00 p.m.	Informal get-together, Faculty Lounge, Student Union

Friday, January 30:

9:00–10:00 a.m. Inspection of College of Engineering and Architecture facilities

10:00 a.m. Meeting, Ferguson Hall, Room 215

1. "Opportunities and Responsibilities of Drawing in an Engineering Educational Program," Professor John T. Rule, Chairman, Section in Graphics, M.I.T.
2. "Graphical Methods for Radium Needle Dosage Calculation in the Treatment of Cancer," Howard W. Vreeland, Assistant Professor of Graphics, Columbia University
3. "Effect of Emphasizing Time in the Teaching of Engineering Drawing," Professor Maurice F. Richards, Santa Barbara College

12:00 noon Luncheon, Student Union

1:15– 3:15 p.m. Inspection Trip to Elgin Watch Company

3:15 p.m. Board Buses for State Capital

3:30– 4:30 p.m. Inspection of State Capital

6:30 p.m. Annual Dinner (Men and Women), Student Union
Speaker: R. G. Gustavson, Chancellor, University of Nebraska

Saturday, January 31:

8:45 a.m. "Manufacturing and Design Problems," Elgin Watch Company, followed by discussion

9:00 a.m. "A Short Terminal Course in Technology," Lyle E. Young, Minnesota Institute of Technology

9:30 a.m. Panel Discussion, "Objectives of a Department of Engineering Drawing" by panel members, C. I. Carlson (University of Illinois); W. E. Street (Texas A.&M.); H. P. Skamser (Michigan State); C. G. Sanders (Iowa State); J. S. Rising (Iowa State), Moderator

12:00 noon Luncheon, Student Union

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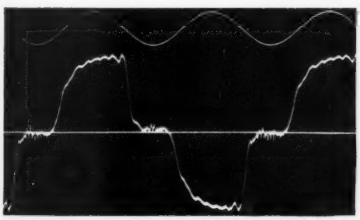

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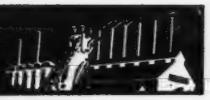
from McGRAW-HILL 

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